AD-A079 320 NERO AND ASSOCIATES INC PORTLAND OR F/G 13/10
TECHNOLOGY ASSESSMENT OF LOW ENERGY VEHICLES.(U)
SEP 79 H A LINSTONE, R DAWSON, Y GUR DOT-CG-835030
UNCLASSIFIED TF019 USCG-D-64-79 NL

1 OF 4
AD
A079320

CG-D-64-79

TECHNOLOGY ASSESSMENT OF LOW ENERGY VEHICLES

DR. HAROLD A. LINSTONE
PROJECT DIRECTOR

DR. RUSSELL DAWSON
YEHUDA GUR
PAUL MOLNAR
DAN SCHWARTZ
DR. KISH SHARMA
JAMES WILSON

September 1979

FINAL REPORT

Document is available to the U.S. public through the
National Technical Information Service,
Springfield, Virginia 22161

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION

United States Coast Guard

Office of Research and Development

Washington, D.C. 20590

NOTICE

DISCLAIMER NOTICE

Technical Report Documentation Page

1. Report No. CG-D-64-79	2. Government Accession No.	3. Recipient's Catalog No. 11

4. Title and Subtitle

6 TECHNOLOGY ASSESSMENT OF LOW ENERGY VEHICLES

5. Report Date: September, 1979

6. Performing Organization Code: 14

7. Author(s) 10 Harold A. Linstone, Russell Dawson, Yehuda Gur, Paul Molnar, Dan Schwartz, Kish Sharma, James Wilson.

8. Performing Organization Report No. TF019

9. Performing Organization Name and Address

Nero & Associates, Inc.
Suite 715, 520 S.W. Sixth Avenue
Portland, Oregon 97204

10. Work Unit No. (TRAIS) 15

11. Contract or Grant No. DOT-CG-835030, SB0408(a)-78-c-168

12. Sponsoring Agency Name and Address

Department of Transportation
United States Coast Guard
Office of Research and Development
Washington, D.C. 20593

13. Type of Report and Period Covered 9 Final Report, August 1978-September 1979

14. Sponsoring Agency Code: G-DMT-3

15. Supplementary Notes

18 USCG 19 D-64-79 12 347

16. Abstract

The objectives of this study are to forecast low energy vehicle technology to the year 2005 and to assess the impact such technological developments may have on U. S. Coast Guard missions, mission requirements, and mission performance.

The tasks undertaken in this study include: (1) 1980-2005 environment and scenarios, (2) mission analysis, (3) technology forecast and assessment, (4) energy analysis, and (5) organizational analysis.

It is found that ELT may replace SAR as the top priority mission. The helicopter, cutter, patrol boat, ports and waterways boat, and fixed wing aircraft will remain high priority vehicles. The currently available Cessna-type aircraft and new lighter-than-air vehicle (LTAV) will also be highly ranked. Other technologically advanced vehicles improve performance (e.g., response time) - an important consideration in view of future "threats" - but at the expense of increased energy consumption. However, they may permit indirect energy savings (e.g., by changes in strategy and tactics).

Key suggested steps for U.S. Coast Guard energy savings include the LTAV, an energy monitoring system, computer-aided mission planning, and production facility to serve eastern and southeastern districts.

Improved power plant and engine component design and remote sensing and communications systems offer other technological opportunities for energy savings.

17. Key Words		18. Distribution Statement
Low Energy Vehicles	Assessments	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161
U.S. Coast Guard	Energy Consumption	
Future Scenarios		
Forecasts		

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

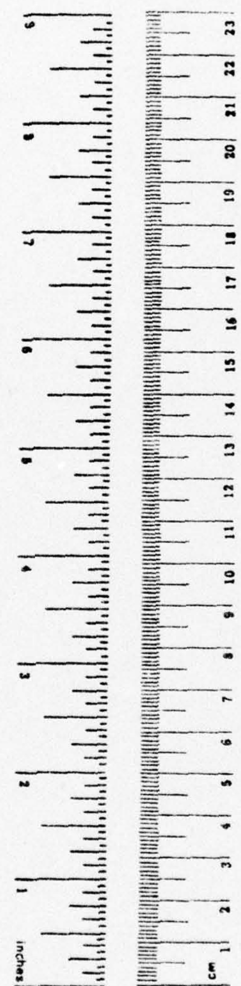
#11530

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

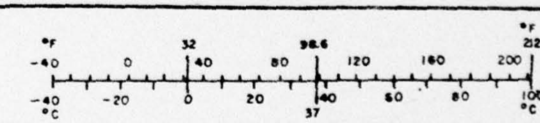


TABLE OF CONTENTS

Table of Contents (continued)

APPENDICES

LIST OF FIGURES

List of Figures (continued)

List of Figures (continued)

APPENDIX FIGURES

List of Figures (continued)

LIST OF TABLES

List of Tables (continued)

APPENDIX TABLES

I. INTRODUCTION AND EXECUTIVE SUMMARY

The objectives of this study are to forecast low energy vehicle technology through the year 2005 and to assess the impact such technological developments may have on the scope of U. S. Coast Guard missions, mission requirements, and mission performance.

Low energy vehicles include current and possible future sea and air vehicles that are characterized by significantly lower energy consumption than comparable conventional vehicles. Technological developments encompass whole vehicles, power plants, or other components, and maintenance procedures which result in significantly reduced energy consumption.

Three basic factors dominate planning for the next quarter century:

(a) The United States is entering a period of transition - from unlimited growth to constrained growth. A primary element in this shift is the reduced availability of natural resources, foremost among which is fossil fuel;

(b) traditional assumptions and trend extrapolations are hazardous in an era of transition;

(c) if energy conservation is the aim, one *must look beyond* vehicles and component technologies to mission strategies and tactics as well as organizational procedures, e.g., training and Standard Operating Procedures (SOP's). This is particularly true for the Coast Guard, which has a very limited role in vehicle research and development.

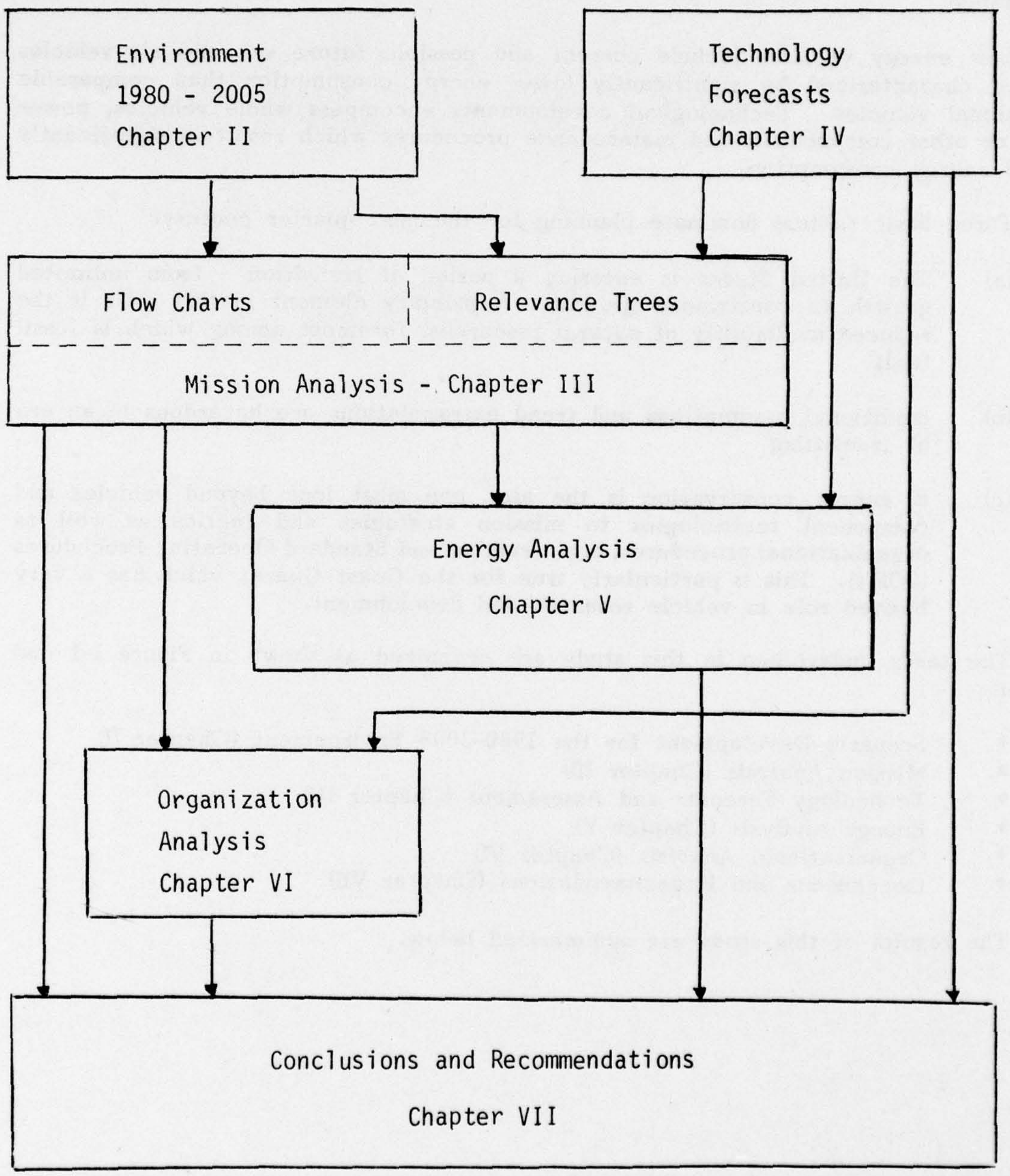
The tasks undertaken in this study are organized as shown in Figure I-1 and include:

* Scenario Development for the 1980-2005 Environment (Chapter II)
* Mission Analysis (Chapter III)
* Technology Forecast and Assessment (Chapter IV)
* Energy Analysis (Chapter V)
* Organizational Analysis (Chapter VI)
* Conclusions and Recommendations (Chapter VII)

The results of this study are summarized below.

FIGURE I-1

REPORT OUTLINE



A. Missions

The relative ranking of the top Coast Guard missions is likely to change between 1980 and 2005. On the basis of three scenarios, it is a "good risk" to assume that SAR will surrender its number one position to ELT. PSS is a significant gainer and MEP is a key concern. Underwater safety and security may become a significant new mission. It will be exceedingly difficult to reverse the trend of the past decade in growth of total energy use, particularly with the anticipated focus on ELT.

Over the scenario period, the helicopter (MRR, SRR) and cutter (WHEC and WMEC) will be the most important vehicles. Patrol boats, ports and waterways boats, and fixed wing (LRS, MRS) aircraft will remain high priority vehicles. The currently available light, general aviation vehicles (Cessna-type) and a new lighter-than-air-vehicle (LTAV) will also be high ranked vehicles.

However, two-thirds of the current Coast Guard fleet will still be operational in 1990.

B. Technological Opportunities

Existing Vehicles: Improved design of power plants and engine components could increase energy efficiency as much as 30%.

New Vehicles: The LTAV is a particularly promising concept. Other major new vehicles improve mission performance (crucial for ELT in the future) but do not directly reduce energy consumption; however, the latter may permit changes in tactics which do reduce overall energy consumption. Future aircraft offer better prospects for energy savings than future ships.

Non-Vehicle Technologies: Advanced remote sensing and communication systems reduce search time and facilitate identification.

Fuels and Energy Technologies: Synthetic fuel, fuel cells, and solar photovoltaic cells have very significant potential, particularly for shipboard applications. An apparently attractive option, some types of synthetic fuels represent an existing technology and are compatible with the large fraction of current vehicles that will still be in service in 1990. Consideration should be given to a move in the direction of Coast Guard selfsufficiency in terms of fuel. A Coast Guard production facility for synthetic fuels should be constructed to serve the eastern and southeastern districts, with other regions following this lead as indicated by need and feasibility.

C. Energy Trade-offs

Monitoring: an energy information system is needed to continuously monitor availability, use, allocation, etc., as a basis for management of the energy budget. Current activities of the Coast Guard in this area represent a good start towards developing a more comprehensive and structured energy information system.

Mission Profile Optimization: A computerized mission planning system analogous to that used by commercial airlines could produce appreciable energy savings.

Fuels: Crude oil derived from oil shale appears more efficient than that derived from coal.

Mission/Vehicle Tactical Analyses: For incident response missions, energy minimization must usually be traded for response time minimization. The "best" current vehicles consume less energy than the "best" higher performance 1990 vehicles, but the most appropriate 1990 vehicles are superior in response time to their current counterparts.

For patrol and surveillance, the situation is different: new vehicles are superior from both the energy and response time points of view.

The choice of the "best" vehicle mix for a given mission cannot be made by a simple rule of thumb. A computer-assisted mission planning system is required for best results.

D. Organizational Aspects

The Coast Guard must deal with growing technological complexity. A characteristic of complex systems is that, to effect significant change, "you can never merely do one thing". In this situation, the simple expansion of the current managerial structure may not be the best approach to handling the new needs. There is a profound concern that sophisticated energy reduction activities will require not only more skilled management and advanced personnel capabilities, but more energy expenditures, thus negating the savings.

Finally, the change in mission priority, from SAR to ELT, threatens to alter the image of the Coast Guard from a humaritarian rescue service to a police force.

E. Key Steps for Low Energy Setting

* LTAV - the most attractive new vehicle; Cessna-type aircraft desirable.

* A strategy to reduce Coast Guard dependence by developing dedicated fuel supplies (small synthetic fuel complex in the east, oil shale plant in the west, small oil refinery in Alaska).

* Consideration of Total Energy System concept.

* Reevaluation of tactical operations: crew size reduction, energy monitoring procedures, computer-aided mission preplanning, changes in tactics, improved vehicle maintenance procedures.

* Changes in organization and training: reduction of on-shore facilities and operations, administrative procedures, personnel training.

* Monitoring of Research and Development: electronic surveillance, engines, automated maintenance.

* Improvement of AN equipment life.

II. 1980 TO 2005: THE ENVIRONMENT

A. BASIC CHANGES

1. Energy

Access to surplus energy has been the overriding means enabling human societies to expand and advance from primitive to highly sophisticated levels. Early hunting and food-gathering tribes were necessarily small and obtained their energy (food and basic materials) from animals and wild plants. These sources were often dispersed, partly mobile, seasonal, and unpredictable. The advent of agriculture resulted in a more reliable and abundant energy supply (and food surpluses) and dramatically increased the earth's carrying capacity. Correspondingly, social organizations became more complex. The industrial use of fossil fuels permitted a further jump in carrying capacity and societal complexity. Historically, the effective depletion of existing energy resources has periodically motivated the development of new energy resources; however, a new energy technology, or energy concept, together with new social structures, were essential in effecting each successful transition. (Figure II-1).

With the depletion of fossil fuels, the United States is again approaching such a transition. The new energy base ultimately chosen will affect the type of society the United States becomes. Two primary, but quite different, energy resources are nuclear fusion and solar radiation. An economy based upon nuclear energy would be necessarily centralized. On the other hand, an economy based upon solar power could be somewhat decentralized. Either could mean a higher or lower quality of life in the United States.

The most rapidly advancing technology today is in the communications/information field. It will also profoundly affect the development of society. Because communications/information technology can facilitate both centralization and decentralization, forecasts of societal direction become more difficult. However, given the existing power structure, a centralized society with a large scale approach to energy production and use is considered more probable.

The transition of complex systems from one stable state to another is never easy or entirely predictable. For example, the current movement of the U.S. from an emphasis upon rapid economic growth to an emphasis upon ecological conservation exhibits serious problems, such as shortages, unemployment, and mismatched incentives and policies. Societies tend to underestimate or entirely ignore the impact of these problems. It is natural to fragment problems, to resist major change, and to pay little attention to the future until a given situation is thought critical.

FIGURE II-1

THE EVOLUTION OF SOCIETIES

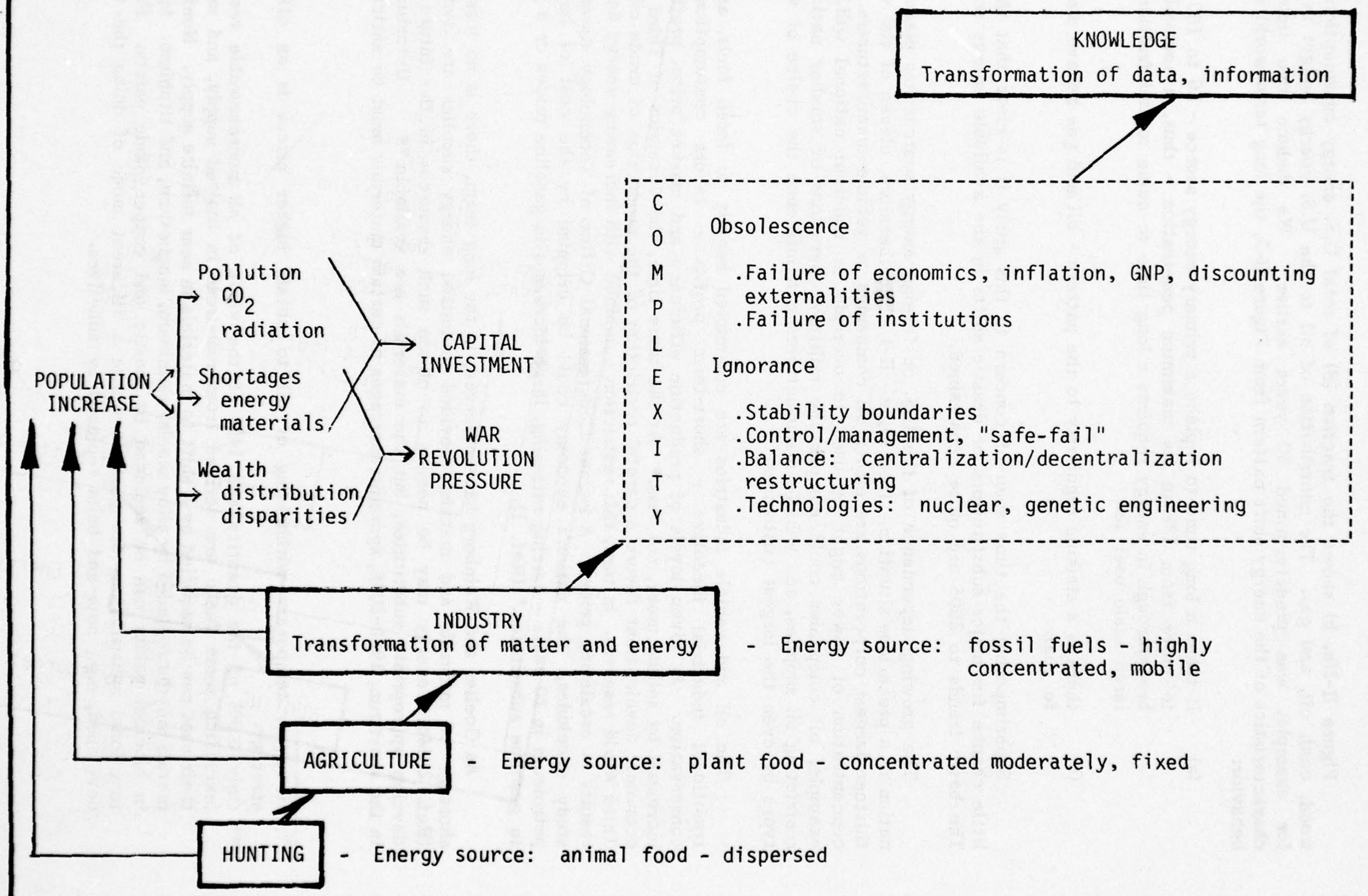


Figure II-2(a, b) shows the fraction (F) of total U.S. energy consumption from wood, coal, oil, and gas. The contribution of oil to the U.S. energy budget in 1965, for example, was predetermined 30 years earlier. We deduce two important characteristics of the energy shift pattern from Figure II-3, the long term world energy behavior:

(a) It takes a long time to replace a primary energy source - 50 to 100 years to move from 1% to its maximum penetration - thus, a technological breakthrough in energy requires a long time to come to full fruition, i.e., large scale use; and

(b) there is a striking regularity to the pattern - oil and gas behave similarly to coal.

Superimposing the time span of concern to this study it is clear that there is little chance for major substitutions or drastic shifts in the available energy sources. The basic trends to 2005 are quite constrained.

The growing dependence of the U.S. on foreign energy sources has placed this nation in a precarious situation. (See Figure II-4). Furthermore, eleven of the world's thirteen largest corporations are either oil companies or vehicle manufacturers. This concentration of power might be used to override or undercut national will. For example, oil companies could hamper the military operations of smaller nations by restricting oil supplies, and vehicle manufacturers can influence the choice of vehicle types by even the largest customers.

The oil and vehicle industries are committed heavily to fossil fuels, and the traditional industrial incentive - short-term profits - favors consumption, not conservation. At given levels of production efficiency and market price, profits are increased by selling more, not less.* At the same time, the dynamics of Third World economic development favors a careful restriction of the production of crude oil from Third World reserves. In turn, this restriction combined with increasing energy demands results in escalating prices. A recent Congressional Office of Technology Assessment study concludes, "the nation's economy could be crippled by the cost of imported petroleum in 20 years - barring rationing, large increases in gasoline prices or a switch to gasoline substitutes." (Ref. 1).

As Goeller and Weinberg have observed, in the long term, there is no forseeable shortage of minerals and metals, provided unlimited energy supplies are available. (Ref. 2).More energy may be needed to obtain such resources in the future or to develop appropriate substitutes, but the materials are available.** Unfortunately, in the short run, 1980-2005, sporadic shortages of certain materials must be anticipated.

* However, temporary withholding of oil to obtain higher prices is an effective strategy.

** Only 0.3% of the quantity and 14% of the value of all nonrenewable resources (excluding some fuels) are derived from resources in limited supply, and most of their uses can be satisfied by a shift to materials in near infinite supply. Nonferrous metals may be replaced by alloy steels, aluminum, magnesium, and titanium. Mercury in biocidal paints can be replaced by plastic and copper oxide paints. Further, functional substitutions are possible where a different mode of doing the task is developed, e.g., nuts and bolts replaced by adhesives.

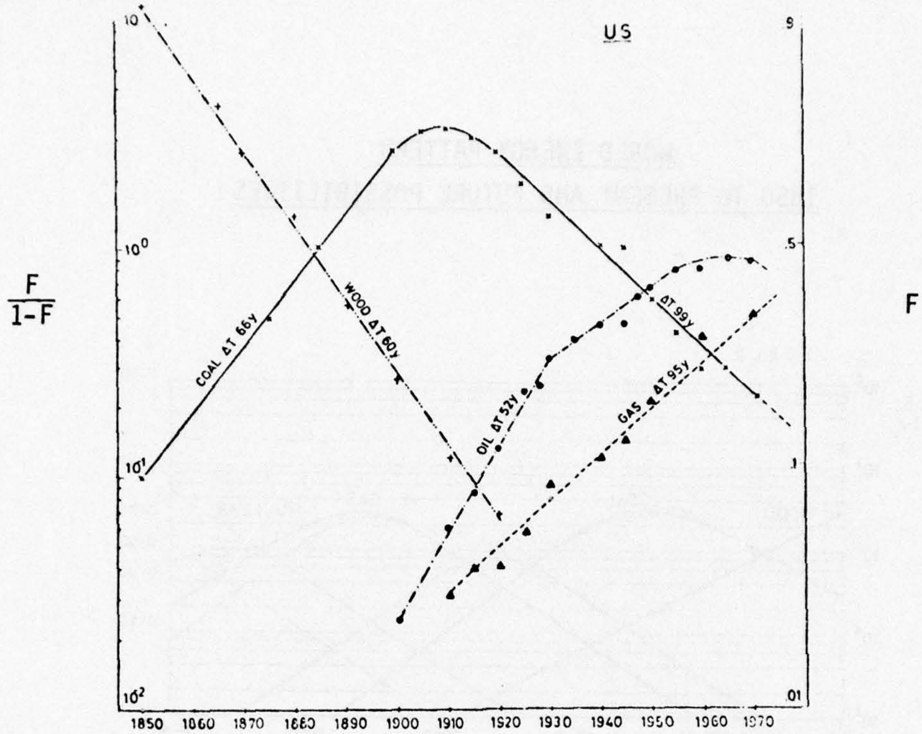


FIGURE II-2a. Fitting of the statistical data on primary energy consumption in the U.S. F = fractional share of total energy. Rates of penetration are indicated by the time to go from 1% to 50% of the market (ΔT years).

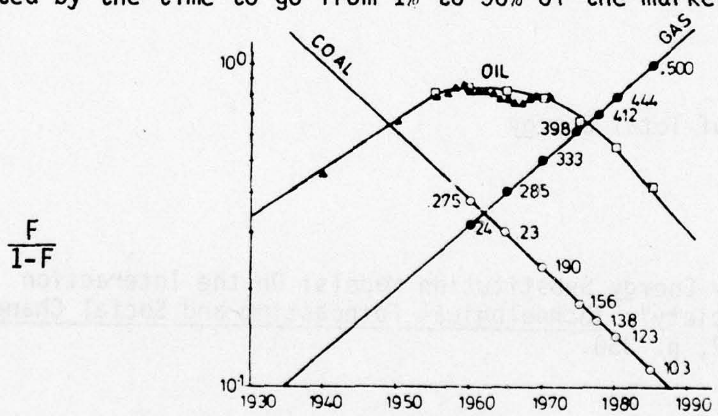


FIGURE II-2b. Forecasting U.S. oil consumption from 1930-1940 trends. F = fractional share of total energy. □ calculated values, Δ statistical data. Other symbols and figures represent intermediate steps in the calculation.

C. Marchetti, "Primary Energy Substitution Models: On the Interaction between Energy and Society", Technological Forecasting and Social Change. Volume 10, No. 4, 1977, p. 349-350.

WORLD ENERGY PATTERN

1850 TO PRESENT AND FUTURE POSSIBILITIES

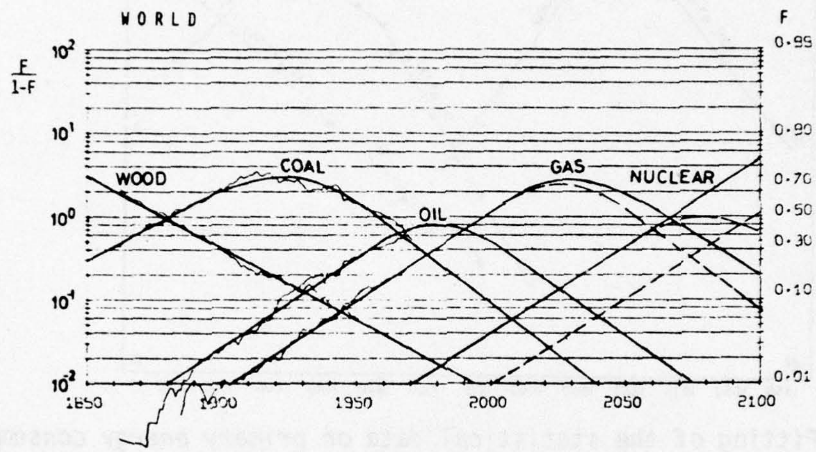


FIGURE II-3
F = Fractional Share of Total Energy

C. Marchetti, "Primary Energy Substitution Models: On the Interaction between Energy and Society", Technological Forecasting and Social Change, Volume 10, No. 4, 1977, p. 350.

2. Population: The Overflow of the Poor

The world population will increase by about 40% in the next 25 years; however, the growth will be distributed unequally between rich and poor areas. Thus, Africa will double in population, while Western Europe will increase barely more than 10%. Table II-1 considers the two groups of nations: those with the 900 million richest and those with the 900 million poorest people.

Of particular concern for Coast Guard planning is Mexico. Its population is doubling from 62 million in 1975 to 130 million in 2000. This is expected to increase the pressure on the U.S.-Mexican border from illegal immigration.

The widening gap between rich and poor nations suggests a growing north-south polarization. Given existing institutions and cultural values, the closure or even the narrowing of this gap presents a superhuman challenge. The Western nations will increasingly become islands of wealth with shores lapped by oceans of surrounding poverty. While $300 billion per year is spent on armaments by the world's nations, economic aid programs fall far short of even the modest goal set by the United Nations, 0.7% of each member state's gross national product.

There are 600 million underfed people in the world today. The famine is largely invisible since the victims are in remote areas, such as the African Sahel. The earth does not lack sufficient means to provide, either now or in 2000, an adequate diet to its population. Rather, agricultural products are not efficiently processed and effectively distributed to the places of need. For example, at the time of World War II, Mexican agriculture could provide only 2000 calories per Mexican. Now it produces enough for 2,600 calories per person.* Yet, there are more undernourished Mexicans today than a generation ago.

A three-pronged threat can be envisioned in the impending confrontation:

(a) Political: Third World countries will continue to form coalitions and regional alliances. In confrontations with the United States, the individual members of these organizations will certainly not stand alone. For example, in a dispute between the European Economic Community and Mexico, most South American states (with a combined population of 400 million in 2000) would probably support Mexico.

(b) Military: Nuclear proliferation is virtually impossible to contain when nuclear bombs can be made solely on the basis of unclassified information. The nuclear non-proliferation treaty has not been signed by either Argentina or Brazil. West Germany has sold Brazil the full array of nuclear reactor and fuel technology, including a fuel-reprocessing plan and a facility for enriching uranium. Brazil is now considered to have the ability to build nuclear weapons. The assumption that only national entities will have nuclear weapons is a serious mistake. Perhaps the most severe threat of the 1980-2005 period is possession of nuclear weapons by terrorists, private armies, guerrillas, or criminals.

* J. & M. McHale use the level 2,370 calories per day as a required minimum averaged over climatic regions and age groups. (Ref. 3).

TABLE II-1

THE GAP BETWEEN RICH AND POOR

Source: J. &. M. McHale

	Rich Group 20 Countries (871 Mill.)	Poor Group 36 Countries (922 Mill.)
Examples	U.S., U.S.S.R., Japan, Germany (West & East)	India, Ethiopia, Haiti, Sudan, Laos, Uganda
GNP/cap.	$4,190	$ 104
Calories/cap/day	3,090	1,961
Energy used/cap (Kg coal equivalent)	4,466	38
Literacy	94%	13%
Life expectancy (male, at birth)	69	39

U.S. PETROLEUM SUPPLY AND DEMAND

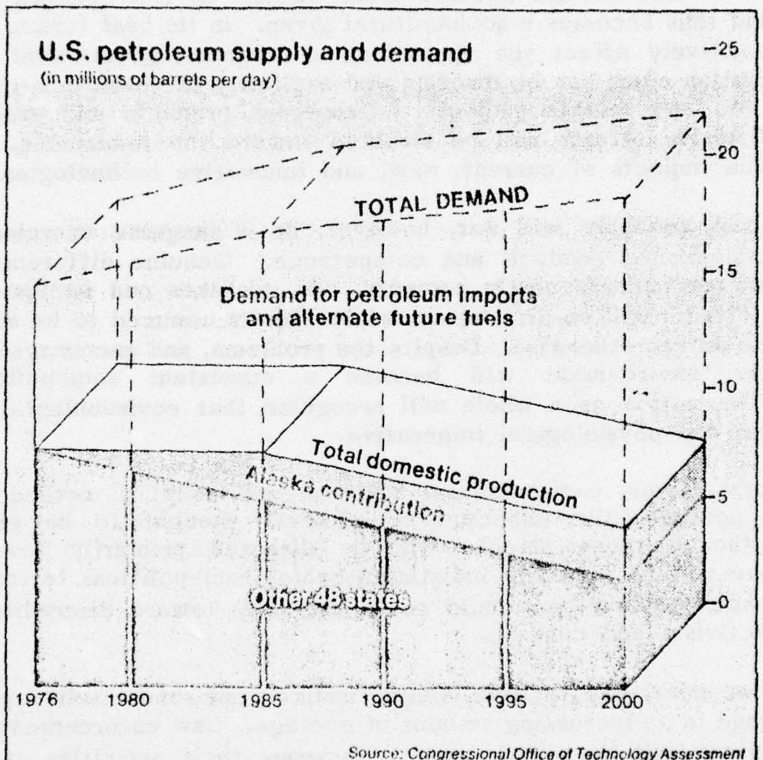


FIGURE II-4

(c) Economic: The less developed countries originate 19% of the world's exports. Of this amount, four-fifths goes to developed countries largely in the form of raw materials, oil, and ore. Oil is a most effective weapon against the United States because of its growing dependence on imported oil. (See Figure II-4). In the long term, due to the feasibility of substitution, the non-fuel materials, e.g., chromite, tin, bauxite, and manganese, do not lend themselves to cartels and boycotts nearly as well as oil does. However, such cartels and boycotts could create critical short-term disruptions.

3. Pollution

The growth of populations and their yearning for material goods produces ever greater industrial development and threatens unprecedented environmental pollution. In the U.S., concern for the quality of the environment has been institutionalized, and, if anything, it will broaden and become more intense as this concern is internalized by individuals and thus becomes a sociocultural given. In its best forms, environmental activism will positively affect the operations of business, government, industry, and individuals. Pollution costs can be directly and explicitly factored into the cost-benefit analyses of public and private projects. Dangerous products and processes will be eliminated, and active efforts will be directed toward the reasonable, non-hysterical assessment of the impacts of current, new, and innovative technologies.

This process probably will not, however, be a sanguine exercise of universal harmony and unblemished goodwill and competence. Genuine differences of opinion, hard fights over particularly costly projects, and mistakes and accidents will occur. Hidden harmful effects will be discovered, while effects assumed to be environmentally dangerous will be proven otherwise. Despite the problems, and encouraged by successes, concern for the environment will become a consistent sociopolitical common denominator. The nation as a whole will recognize that environmental responsibility is a sociocultural and physiological imperative.

In its worst forms, environmental activism will adopt a methodology centered upon so-called ecotage, the sabotage of projects thought to be environmentally hazardous. Although these attacks will be directed primarily toward industrial installations, they will be virtually indistinguishable from political terrorist activities. Further, these acts of sabotage could go a long way toward discrediting legitimate environmental activism and concern.

During the next twenty five years, radical environmentalist groups can be expected to engage in an increasing amount of ecotage. Law enforcement and domestic intelligence services will be called upon to increase their activities of enforcement, monitoring, and patrol. "Targeted" projects will have to increase their security precautions. Environmental activists will find it difficult to conduct their day to day activities and demonstrations without falling under suspicion. The general public will suffer from an increasing level of civil unrest and from the constriction of action and, more importantly, information exchange.

A prime area of concern is that of nuclear pollution. Unless properly designed, managed, and regulated - a condition which a growing number of experts and concerned laymen assert is not possible given the current level of scientific knowledge - nuclear installations can cause environmental pollution in a number of ways. The three most commonly cited are:

(a) Radiation from operation (in point of fact, it is not currently known what levels of increased background radiation are safe in the short and long terms);
(b) radioactivity released in massive amounts as a result of a catastrophic accident, such as a core meltdown;
(c) leakage from waste disposal sites.

With the vast number of new industrial processes and products, the number and quantity of new chemical compounds released into the environment is growing at an awesome rate. It is estimated that 5000 new compounds are produced annually and that adequate testing is virtually impossible. By 2005, severe new environmental problems are likely to absorb the nation's attention.

The cumulative effects of pollution suggest the policing of waterways and oceans will be increasingly important.

4. Technology

The two aspects most pertinent to this study are discussed below.

(a) Telecommunications: The processing and movement of goods, people, and information are primary human activities. (See Table II-2.) There are two critical differences between goods and people on the one hand and information on the other: (1) The processing and/or movement of goods and people requires large amounts of energy; the processing and/or movement of information does not. (2) The transfer of goods and people usually involves a loss to one party and a gain to another; the tranfer of information involves no such loss. Venezuelan oil used in the U.S. is lost to the world forever; Oregon trees cut down are lost until new ones grow. On the other hand, information transferred from one person to another is not lost to the giver.

Telecommunications and transportation are shrinking the earth to a global village. The population explosion and the material goods now available have created resource problems in this global village. In the long run, these will be solved as Goeller and Weinberg (Ref. 2) have noted. Massive substitutions of materials depends entirely on an economic supply of energy not now at hand. Although solar and/or nuclear fusion energy will solve this problem, sometime after 2000, we now face a serious, albeit temporary, dilemma of large magnitude.

In this context, the advantage of information over material goods becomes significant for the 1980-2005 period.

There is also an inherent critical similarity between goods and people on the one hand, and information on the other. In any complex living system the movement of both material and information is essential to survival and evolution. Communication is crucial to the management of system growth and complexity, i.e., to self-reorganization. The avoidance of excessive centralization or decentralization depends on adequate communications.

TABLE II-2

EXTENSIONS OF HUMAN CAPABILITY

			Paleolithic	Today
Processing	(A)	Human	Natural processes	Medicine
		Material	Stone - Flake tool	Mechanical/Chemical/ Biological Engineering
	(B)	Information	Brain	Computer
Movement	(A)	Human	Walking	Aircraft, Space Shuttle
		Material	Carrying	Train, Ship, Aircraft, Missile, Truck
	(B)	Information	Speech, Symbols	Telecommunications

It is evident today that serious weaknesses in communications exist. At the global level, these weaknesses have exacerbated problems with security against nuclear holocaust, equitable allocation of limited resources, and avoidance of global economic collapse. At the national level, these problem areas include the bureaucracy, unsound fiscal policies, the inability to manage national energy policy, and the excessive power of special interests. At the local level, these problems include a lack of autonomy, and a lack of access to expertise.

Among the telecommunications trends of the next twenty years, the following are particularly noteworthy:

Integrative video terminal: As common in 2000 as the telephone was in 1930, the integrated video terminal will be used for remote shopping, access to libraries, household budgeting and bill paying, and office contacts, including conferencing, electronic mail, electronic newspaper, etc.

Private and public networks of all kinds: This system will include medical diagnostics using large data bases, energy allocation and monitoring systems, participative governance, and widespread electronic funds transfer. Telecommunications will be used and misused in many new ways. In the latter category we cite two illustrations: Cybernetic surveillance to a degree which would make Watergate look trivial, and the creation of a new class of disenfranchised persons lacking the ability to electronically access information.

(b) Energy: Until 1990, the nation faces continued reliance on conventional fuel sources, particularly oil, natural gas and coal. During this period the transportation sector will continue to rely on petroleum-based fuels, such as gasoline, jet fuel, and diesel. Although currently in use, electric vehicles are not expected to penetrate the market in significant quantities. The quality of fuels for the airplanes and ships will continue at current levels. The inertia, magnitude of dependency, and interconnectedness of the production and distribution system are so substantial that the transportation sector will undergo few changes with respect to new alternative fuels. The driving force for changing patterns of the energy use in transportation will derive from government insistence on energy conservation.

During the 1990-2005 period, a recognizable transition from conventional to alternative fuel technologies will begin. If current research and development plans are fully implemented, this period should see increased reliance on coal gasification and liquefaction. The development of processes to produce methane quality gas fuels from coal will be somewhat ahead of those to produce liquid fuels, particularly synthetic crude oil and solvent refined coal.

The present emphasis upon passive solar systems will shift to active solar systems. These active systems include photovoltaics and solar thermal, sometimes referred to as the "power tower" concept. These can become significant sources of electricity production. Of the two technologies, photovoltaics should be of particular significance to Coast Guard missions.

The future of nuclear power is uncertain at best. Problems and issues related to waste disposal and changing sociopolitical attitudes beset the present fission-based technologies. Although nuclear fusion shows promise, research and development in this area have yet to produce the breakthroughs needed to increase confidence in this option's viability. During the 1980-2005 period, these breakthroughs could occur; however, considering the probable lead times necessary for the deployment of such plants, large-scale nuclear fusion remains a doubtful proposition for this study's period of interest.

B. CROSS IMPACT ANALYSIS

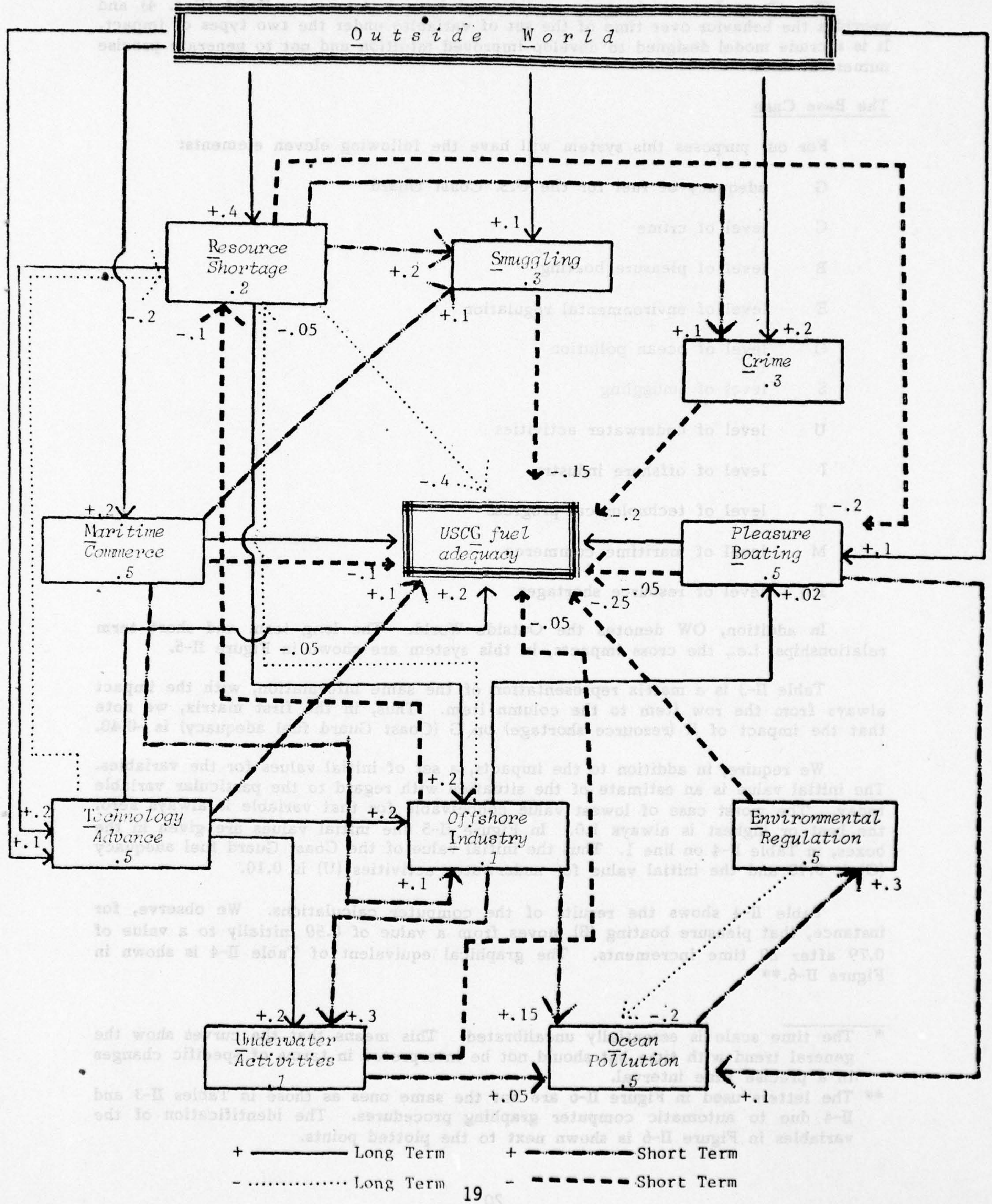
Cross Impact Analysis refers to the study of the impact of one factor upon another (e.g., the impact of offshore industry on Coast Guard fuel adequacy). Unlike the situation in classical physics and simple man-made systems, we cannot assume that one variable changes over time and everything else remains unchanged (this is the well-known "other things being equal" or ceteris paribus assumption). In a complex system it is likely that virtually everything affects everything. This situation creates difficulties for our intuition and cross-impact analysis has, as its aim, the clarification of the behavior of variables in complex systems where we cannot rely on intuition. Figure II-5 illustrates a view of the Coast Guard fuel problem and its relationship to other important variables in the 1980-2005 period. There are twelve variables shown and two types of impact. One is a long-term impact which is of a cumulative nature. A cumulative impact is that of a rate impact.* The second type of impact is a short term or proportional one. Both impacts may be positive or negative. An example of a long term impact is the depletion of resources as a result of fossil fuel shortages. A constant rate of fuel use lowers the available fuel resources. On the other hand, the effect of smuggling on Coast Guard fuel use is primarily proportional, i.e., as smuggling increases the Coast Guard sorties increase, if smuggling remains constant the Coast Guard sorties to counter smuggling remain constant.

---

* An example of a cumulative impact is the savings account where a constant positive rate of interest increases the savings over time.

THE BASE CASE

FIGURE II-5



The Cross Impact Analysis model used here is known as KSIM (Ref. 4) and provides the behavior over time of the set of variables under the two types of impact. It is a crude model designed to develop improved intuition and not to generate precise numerical data.*

The Base Case

For our purposes this system will have the following eleven elements:

G adequacy of fuel for the U.S. Coast Guard

C level of crime

B level of pleasure boating

E level of environmental regulation

O level of ocean pollution

S level of smuggling

U level of underwater activities

I level of offshore industry

T level of technological progress

M level of maritime commerce

R level of resource shortages

In addition, OW denotes the Outside World. The long term and short term relationships, i.e., the cross impacts, in this system are shown in Figure II-5.

Table II-3 is a matrix representation of the same information, with the impact always from the row item to the column item. Thus, in the first matrix, we note that the impact of R (resource shortage) on G (Coast Guard fuel adequacy) is -0.40.

We require, in addition to the impacts, a set of initial values for the variables. The initial value is an estimate of the situation with regard to the particular variable today. The worst case of lowest value conceivable for that variable is always zero, the best or highest is always 1.0. In Figure II-5 the initial values are given in the boxes, in Table II-4 on line 1. Thus the initial value of the Coast Guard fuel adequacy (G) is 0.90 and the initial value for underwater activities (U) is 0.10.

Table II-4 shows the results of the computer calculations. We observe, for instance, that pleasure boating (B) moves from a value of 0.50 initially to a value of 0.79 after 20 time increments. The graphical equivalent of Table II-4 is shown in Figure II-6.**

---

* The time scale is essentially uncalibrated. This means that the curves show the general trend with time but should not be interpreted in terms of specific changes in a precise time interval.

** The letters used in Figure II-6 are not the same ones as those in Tables II-3 and II-4 due to automatic computer graphing procedures. The identification of the variables in Figure II-6 is shown next to the plotted points.

CROSS IMPACTS - BASE CASE

TABLE II-3

ALPHA VALUES - cumulative impacts (long term)

		G	C	B	E	O	S	U	I	T	M	R	OW
		1	2	3	4	5	6	7	8	9	10	11	12
G	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E	4	0.00	0.00	0.00	0.00	-0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	8	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.05	0.00
T	9	0.20	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	-0.20	0.00
M	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R	11	-0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00
OW	12	0.00	0.20	0.10	0.00	0.00	0.10	0.00	0.00	0.10	0.20	0.40	0.00

BETA VALUES - proportional impacts (short term)

		G	C	B	E	O	S	U	I	T	M	R	OW
		1	2	3	4	5	6	7	8	9	10	11	12
G	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	2	-0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	3	-0.05	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E	4	-0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O	5	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	6	-0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U	7	-0.05	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	8	0.00	0.00	0.00	0.00	0.15	0.00	0.30	0.00	0.00	0.00	-0.10	0.00
T	9	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	10	-0.10	0.00	0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00
R	11	0.00	0.10	-0.20	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00
OW	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

OUTPUT - BASE CASE

TABLE II-4

COAST GUARD MARK 13.0 (KSIM)

TIME UNIT ↓	G 1	C 2	B 3	E 4	O 5	S 6	U 7	I 8	T 9	M 10	R 11	OW 12
1.0	0.90	0.30	0.50	0.50	0.50	0.30	0.10	0.10	0.50	0.50	0.20	0.50
2.0	0.90	0.33	0.52	0.50	0.47	0.32	0.12	0.13	0.53	0.53	0.23	0.50
3.0	0.89	0.38	0.52	0.47	0.47	0.36	0.18	0.17	0.56	0.56	0.24	0.50
4.0	0.89	0.42	0.52	0.47	0.48	0.40	0.24	0.22	0.59	0.59	0.25	0.50
5.0	0.87	0.46	0.53	0.48	0.49	0.44	0.33	0.27	0.62	0.62	0.26	0.50
6.0	0.85	0.49	0.55	0.49	0.51	0.47	0.42	0.33	0.65	0.65	0.26	0.50
7.0	0.83	0.53	0.56	0.51	0.54	0.50	0.51	0.39	0.67	0.68	0.26	0.50
8.0	0.81	0.56	0.58	0.54	0.56	0.52	0.60	0.46	0.70	0.70	0.26	0.50
9.0	0.78	0.59	0.60	0.56	0.58	0.54	0.68	0.52	0.72	0.72	0.25	0.50
10.0	0.76	0.61	0.62	0.58	0.60	0.56	0.75	0.58	0.74	0.75	0.24	0.50
11.0	0.73	0.64	0.65	0.59	0.61	0.58	0.81	0.63	0.76	0.77	0.23	0.50
12.0	0.72	0.66	0.67	0.61	0.62	0.59	0.85	0.68	0.78	0.78	0.22	0.50
13.0	0.70	0.69	0.69	0.61	0.62	0.61	0.88	0.73	0.80	0.80	0.21	0.50
14.0	0.70	0.71	0.71	0.62	0.62	0.62	0.91	0.77	0.81	0.82	0.20	0.50
15.0	0.69	0.73	0.73	0.62	0.62	0.63	0.93	0.80	0.83	0.83	0.19	0.50
16.0	0.70	0.75	0.75	0.61	0.61	0.65	0.94	0.83	0.84	0.85	0.18	0.50
17.0	0.70	0.76	0.77	0.61	0.60	0.66	0.95	0.86	0.85	0.86	0.17	0.50
18.0	0.71	0.78	0.78	0.60	0.59	0.67	0.96	0.88	0.86	0.87	0.16	0.50
19.0	0.73	0.80	0.80	0.59	0.57	0.68	0.97	0.90	0.87	0.88	0.15	0.50
20.0	0.74	0.81	0.81	0.57	0.56	0.69	0.98	0.92	0.88	0.89	0.14	0.50

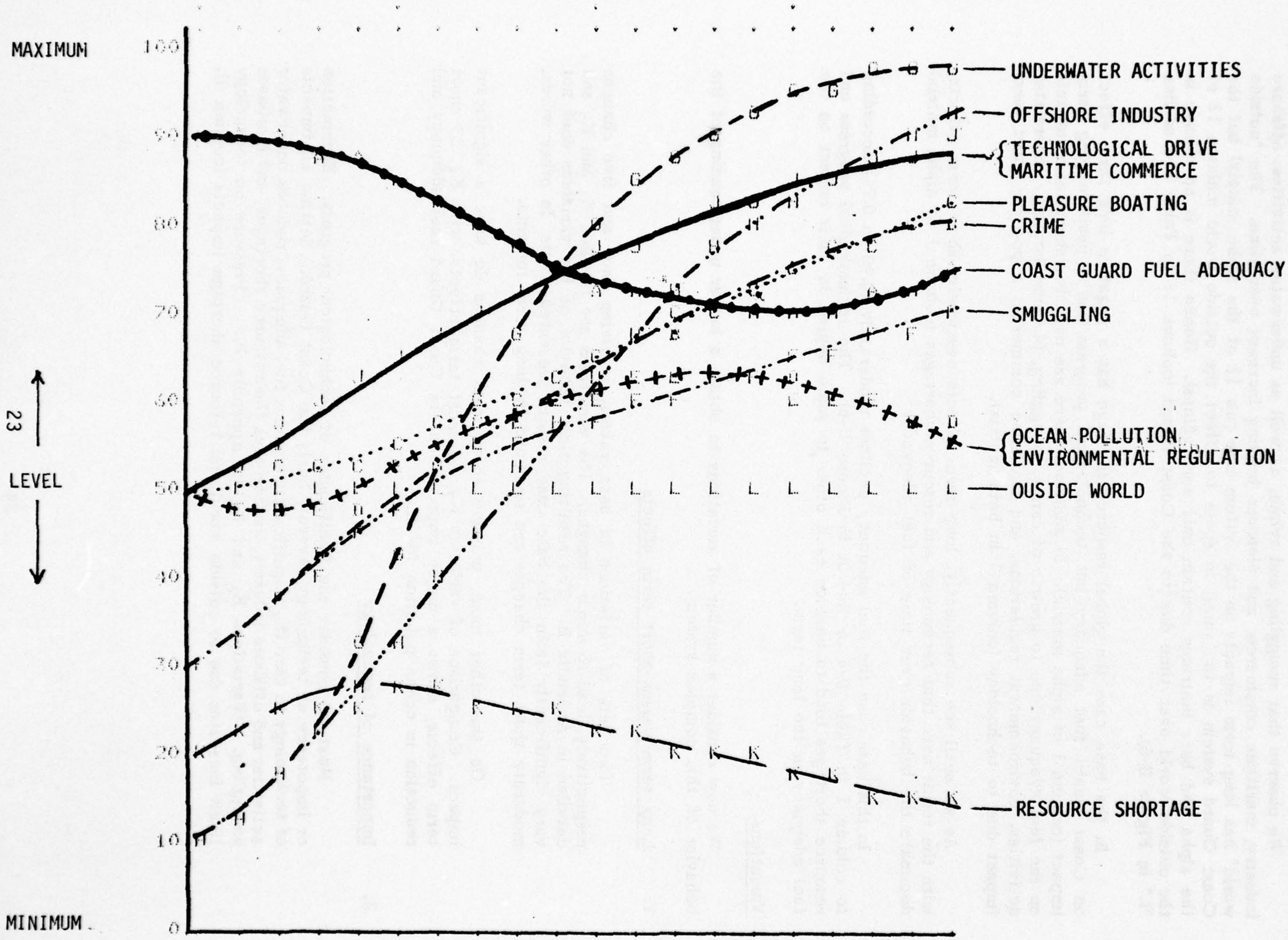


FIGURE II-6

*Time scale is uncalibrated in this model

We observe that smuggling and crime, as well as underwater activities, offshore industry, maritime commerce, and pleasure boating increase over time. The "outside world" has long term impacts on the system (see row 12 of the alpha matrix) but the Coast Guard system is too small in scale to affect the outside world (column 12 of the alpha and beta matrices contain only zero values). Hence there is no change in the outside world over time due to the Coast Guard (column 12 in Table II-4 or line "L" in Figure II-6).

In the base case the global resource shortage has a negative long term effect on Coast Guard fuel adequacy but technological progress has a positive long term impact (column 1 of alpha matrix). In addition, there are negative short term impacts on the fuel adequacy due to growth of crime, smuggling, pleasure boating, underwater activities, environmental regulations, and maritime commerce; a positive short term impact due to technology (column 1 in beta matrix).

As we shall see subsequently, long term effects overwhelm short term effects, with the result here that technology and resource shortages (column 1 of alpha matrix) dominate the behavior over time of fuel adequacy.

In this base case the fuel adequacy declines moderately (0.90 to 0.74) according to column 1 in Table II-4 or line A in Figure II-6). The technological progress and resource shortages tend to balance each other to some degree in their impact on the fuel adequacy in the long term.

Variations

We now consider a number of variations to obtain a better understanding of the behavior of this complex system.

1. Long term versus short term effects

Two sets of variations in beta values, involving four and five changes respectively, lead to minor changes. The variations are labelled K_1 and K_3 and detailed in Appendix B. The resulting time behavior of the variables does not vary significantly from the base case results presented above. In other words, moderate short term changes are swamped by long term impacts.

On the other hand, massive short term changes do have a significant impact. Comparison of variation K_7, no short term effects, with K_5, 23 short term effects, shows a major improvement in Coast Guard fuel adequacy and reduction in ocean pollution for K_7.

2. Importance of technology

Next we consider the significance of technological progress. Elimination or impotence of technology severely hurts the Coast Guard. Setting all impacts of technology to zero (K_6) significantly worsens fuel adequacy, reduces underwater activities and offshore industry, exacerbates the resource shortages, and increases smuggling. (Variations K_6 and K_5 in Appendix B). Pressure on technology itself increases due to outside world and resource shortage impacts (column 9).

If we strengthen technological progress (both short and long term in K_8), there is a significant beneficial effect on Coast Guard fuel adequacy. The increased positive impacts of technology are seen by comparing row 9 of variations K5 and K8 for both alpha as well as beta matrices (Appendix B).

The typical behavior of complex systems is illustrated by the fact that ocean pollution is not eliminated by technological progress as might be intuitively assumed. Accelerated technological progress increases underwater activities and offshore industry, but thereby ocean pollution is increased. The relation between environmental regulation and ocean pollution tends to stabilize both: as pollution increases regulation increases; as regulation increases pollution decreases; as pollution decreases regulation decreases; as regulation decreases pollution increases; etc.

These examples suggest the subtlety of complex system behavior and the truth of Garret Hardin's maxim: "you can never merely do one thing".

C. SCENARIOS

1. The Scenario Concept

A scenario is an outline of a hypothetical "future history". It is designed to allow a more holistic consideration of alternative futures than trend extrapolations and analytic models.

A given scenario can be viewed as one of an infinite number of possible paths from the present to the future in an n-dimensional space (where "n" is a very large number). This concept is sketched in Figure II-7. Since the number of paths is so large, the probability of each one is very small. Each path involves the occurrence and non-occurrence of many individual events; therefore the resulting path probability is the product of many event probabilities. Such a product must be exceedingly small.* Thus, a scenario cannot be measured by its specific likelihood of occurrence, and terms such as "the most likely scenario" are inherently meaningless.

A scenario, like a war game, cannot forecast what will happen. Rather, it can sensitize the participant to what can happen, thus improving decision making ability.

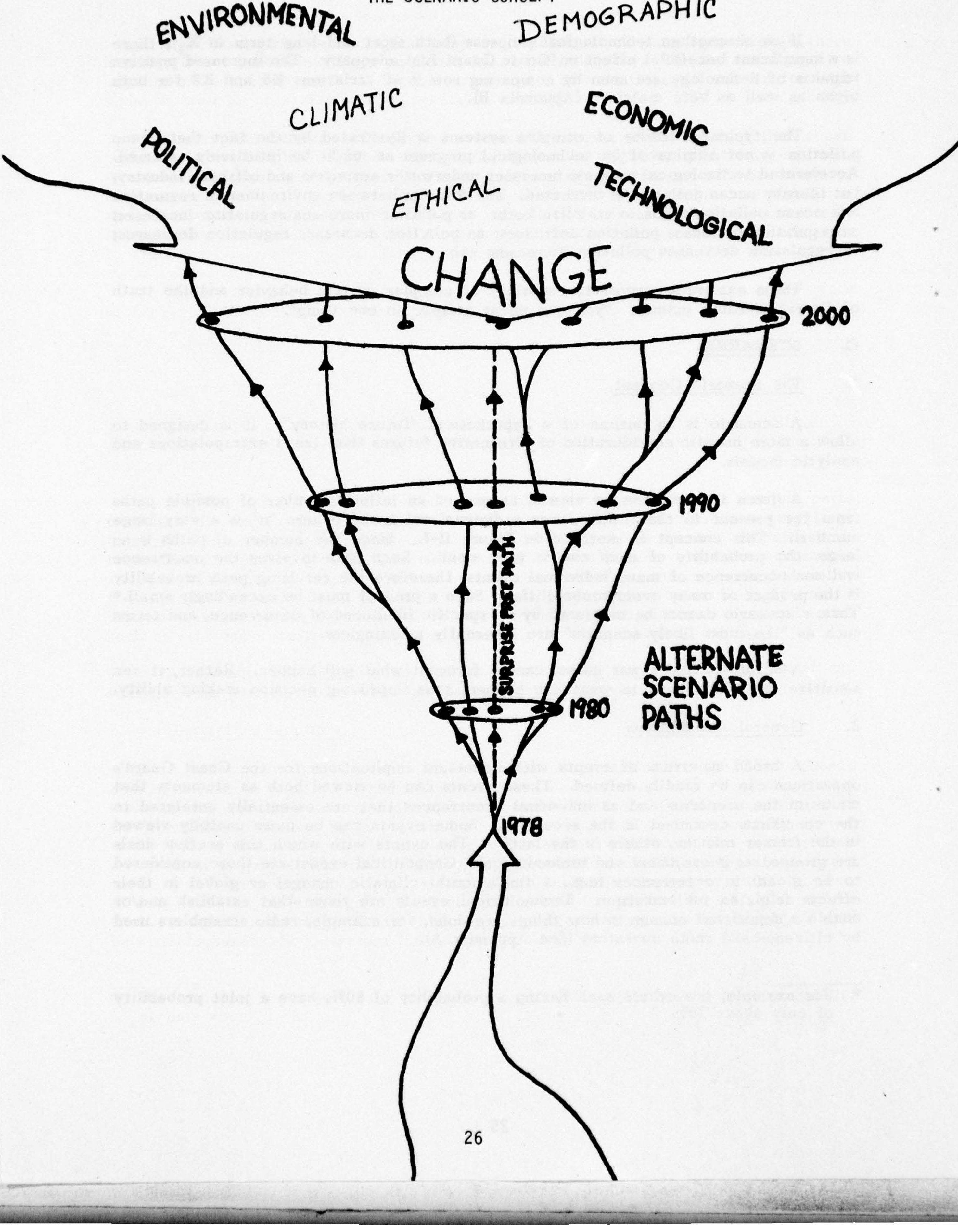
2. General Assumptions

A broad spectrum of events with important implications for the Coast Guard's operations can be readily defined. These events can be viewed both as elements that make up the scenarios and as individual occurrences that are essentially unrelated to the conditions described in the scenarios. Some events can be more usefully viewed in the former manner, others in the latter. The events with which this section deals are grouped as geopolitical and technological. Geopolitical events are those considered to be global in occurrences (e.g., a fundamental climatic change) or global in their effects (e.g., an oil embargo). Technological events are those that establish and/or enable a significant change in how things are done, for example, radio scramblers used by citizens-band radio operators (See Appendix A).

---

* For example, ten events each having a probability of 80%, have a joint probability of only about 10%.

FIGURE II-7
THE SCENARIO CONCEPT



Several assumptions can be made about the sociopolitical objectives of the United States. The following list of objectives is not complete; nor does it necessarily contain those objectives which are most essential to the United States. However, these objectives will play a vital role in the determination of national policy over the period covered by this study.

At the national level:

(a) reduce national dependence upon foreign energy sources:
 (1) develop new supplies and sources;
 (2) conserve existing supplies;
 (3) increase the efficiency with which existing supplies are used;
(b) to develop a method(s) for the long-term safe disposal and/or storage of hazardous wastes;
(c) prevent terrorist activities;
(d) play an active role in the maintenance of world order;
(e) main an adequate national military capability;
(f) further develop the national transportation system;
(g) eliminate the potential for harmful drug abuse;
(h) effectively control environmental pollution;
(i) prevent irremediable damage to the environment;
(j) protect life and property;
(k) provide and protect adequate food supplies for all citizens;
(l) develop and implement a comprehensive oceans policy.

Within the structure of these national objectives, the United States Department of Transportation has identified several additional objectives. A partial list includes:

(a) increase the economic efficiency and service of the national transportation system;
(b) improve the safety and security of transportation;
(c) lessen the unfavorable environmental effects of transportation, particularly of crude oil, petroleum products, and other hazardous or potentially hazardous materials;
(d) minimize the adverse effects of an energy shortage upon the nation's transportation system;
(e) modernize the regulation and legislation governing transportation;
(f) increase the knowledge base regarding transportation and related areas;
(g) support other national interests.

Within these structures, several assumptions about the nature of the Coast Guard during the period covered by this study can be made. A partial list includes:

(a) the Coast Guard will continue as a single organizational entity;
(b) the Coast Guard will remain a uniformed component of the United States Armed forces;

(c) although many activities will increasingly focus on regulation and prevention the Coast Guard will remain an "operational" organization;

(d) the Coast Guard will actively pursue the accomplishment of national objectives as appropriate;

(e) although there is some chance that the Coast Guard and other marine related services and departments, other than the Navy, will be merged into a "Department of Maritime Affairs", the present likelihood is that the Coast Guard will remain in the Department of Transportation during the next several decades;

(f) the peacetime activities of the Coast Guard will continue to center around civil marine and maritime matters and activities;

(g) the Coast Guard will remain an integral, service-type organization, exercising, within the Department of Transportation, a leading advisory role in maritime affairs. (Refs. 5, 6).

3. Key Scenario Descriptions

Our three paths into the future (Figure II-8) are described in this study in two ways, narrative scenario sketches (Appendix A3) and a convenient shorthand involving six variables which can take on twenty values (Table II-5). The latter are defined in a concise form below.

Explanation of Factors

Coastal Threat (T)

This variable measures the threat to American coasts, ports, outer-continental shelf installations, and coastal traffic posed by domestic and foreign-based terrorists and criminals. Such activity is considered an informal threat. A formal threat would result from the direct activities of a hostile soverign power and would be monitored by the Navy. While terrorist or criminal acts are included in this variable, overt acts of war are not.

Variable Values (T)

T_1 - Low. The threat to United States coastal areas continues at about the level of the late 1970's.

T_2 - Moderate Increase. The levels of violence and threat in the coastal areas of the United States show a moderate increase over the levels of the late 1970's. Sporadic terrorist activities occur somewhat similar to PLO infiltrations from the sea onto Israel's coast.

T_3 - Large Increase. The levels of violence and threat in American coastal areas show a large increase over those of the 1970's. Domestic and international terrorism directed toward off-shore and coastal installations markedly increases. The likely motivations for these groups include: psychological instability, crime, domestic manifestations of foreign movements, domestic political revolution, radical "ecological" movements (ecotage), industrial labor-relations conflicts, inter-corporate and intra-corporate conflicts, and proxy aggression against the United States.

FIGURE II-8

THREE SCENARIOS

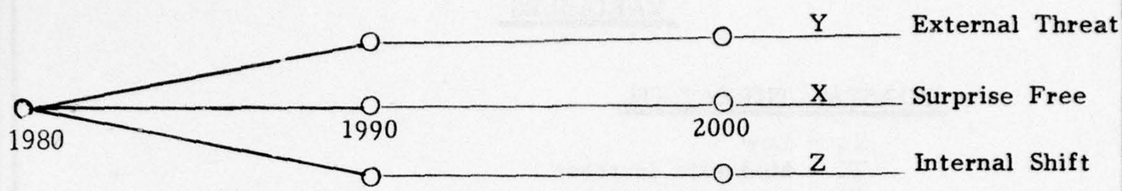


TABLE II-5

VARIABLES

COASTAL THREAT (T)

T_1 - Low
T_2 - Moderate Increase
T_3 - Large Increase

ENVIRONMENTAL REGULATION (E)

E_1 - Minor Concern
E_2 - Current Level
E_3 - Stringent Regulation - United States
E_4 - Stringent Regulation - International
E_5 - Regulation (Monitoring)

CRIME (C)

C_1 - Reduced
C_2 - Current
C_3 - Increased

LEISURE ACTIVITIES (L)

L_1 - Reduced
L_2 - Current
L_3 - Large Increase

MARINE RESOURCE USE (R)

R_1 - Current
R_2 - Major Increase
R_3 - Very large Increase

U. S. COAST GUARD BUDGET (B)

B_1 - Decrease
B_2 - Constant
B_3 - Increase

In a condition of T_3, violence is considered a common occurrence. As a result, coastal areas, offshore installations, and ships and small craft become heavily armed. Recreational boaters not only check the life jackets and pack the food, but also the shotgun.

Environmental Regulations (E)

This variable measures the stringency, scope, and enforcement of local, national, and international environmental protection regulations. As mining, manufacturing, and energy generation activities are increasingly located offshore, resulting in greater vulnerability to accident and sabotage, it will become necessary to enact and enforce a growing number of environmental protection laws. Environmental and enforcement regulation will probably lag behind the actual development of the offshore facilities. Thus, its likely mode will be crisis response, with widely varying degrees of competence and effectiveness.

Variable Values (E)

E_1 - Minor Concerns. The stringency and enforcement of environmental regulation is reduced as a result of economic, social and/or geopolitical concerns. It is possible that worsening economic conditions, dwindling resources, and a need for full employment will force a relaxation of environmental protection regulations. A movement of this type can already be seen with respect to coal.

E_2 - Current Level. The character of environmental protection legislation remains similar to that of the late 1970's. In terms of Coast Guard activities, the major focus is on the prevention and clean-up of oil spills, chemical dumping, and other pollution.

E_3 - Stringent Regulations - United States Only. As a result of public pressure, stringent regulations are enacted and enforced. However, these measures are limited to the coastal areas of the United States.

E_4 - Stringent Regulations - International. As a result of public pressure in a number of countries, and due to the confusion of frequently differing regulations and enforcement procedures, truly international environmental protection agreements and treaties are enacted. The objective of these new international agreements is to rationalize, regularize, and coordinate efforts to protect the maritime environment.

E_5 - Regulation and Monitoring. Unlike levels E_1 through E_4 in which environmental activities are largely reactive in nature, E_5 represents a condition in which the marine environment is actively monitored for potential threats and general condition.

Domestic and International Crime (C)

This variable measures the level of crime in the society with special emphasis on those crimes that are water-related, including the smuggling of goods and people and maritime hijacking.

Variable Values (C)

C_1 - Reduced Levels. This value represents a reduction in the crime level from that of the late 1970's. It is conceivable that certain illegal goods could become legal, and that immigration policies could become less stringent. Under such circumstances, the incidence of associated crimes would, of course, decline.

C_2 - Current Level. Crime in coastal areas continues at approximately the level of the late 1970's.

C_3 - Large Increase. Given the extension and/or acceleration of current trends, crime in coastal areas increases.

Drug smuggling increases, as use becomes further widespread and more socially acceptable. This, in turn, could mitigate the Coast Guard's ability to perform its more important tasks, such as search and rescue and suppression of hard-drug traffic. Smuggling of illegal aliens, scarce raw materials, and goods also increases markedly. The current size of the problem of the "boat people" from Viet Nam is suggestive of the scale of illegal movement envisioned here.

Leisure Activities (L)

This variable measures the amount of recreational activity that takes place in areas under Coast Guard jurisdiction. These activities include swimming, flying over water, boating, diving, operating small submersibles, and fishing. This variable reflects the manufacture, sale, and service of related equipment.

Variable Values (L)

L_1 - Reduced Level. Under conditions national economic decline and increased crime and/or terrorism, recreation in coastal areas could be severely affected. As coastal areas become more dangerous and/or more polluted, people will seek recreational opportunities inland.

L_2 - Current Level. Water related recreational activities occur at about the same level as in the late 1970's.

L_3 - Large Increase. Water-related recreational activities increase substantially over the level of the late 1970's. Such pastimes as fishing, diving, hang-gliding, long distance cruising, and the recreational use of underwater vehicles are increasing rapidly and are becoming economically more feasible, leading to greater volume of offshore recreational traffic.

Marine Resource Use (R)

This variable measures the extent to which oceans and coastal areas become suitable for mining, crude-oil and natural gas production, mariculture, energy generation, and related activities.

Variable Values (R)

R_1 - Current Level. Resource extraction in maritime areas continues at roughly the current levels. The scope and nature of the projects involved may change, but the overall level remains virtually constant. This could occur for a number of reasons. Terrorist activity could directly and indirectly (through higher insurance and interest rates) discourage investment. Economic or environmental constraints may render such activities infeasible.

R_2 - Major Increase. As a result of various political, natural resource, and economic pressures, the extraction of resources in maritime areas increase markedly over the levels of the late 1970's.

R_3 - Very Large Increase. A "marine economy" becomes a major national goal, analogous to the Apollo program of the 1960's.

United States Coast Guard Budget (B)

This variable measures the Coast Guard budget.

Variable Values (B)

B_1 - Decrease. The Coast Guard budget decreases significantly in real terms.

B_2 - Constant. The Coast Guard budget remains the same in real terms.

B_3 - Increase. The Coast Guard budget increases significantly in real terms.

We now transform the narrative sketches of scenarios X, Y, and Z (Appendix A3) into this shorthand notation, obtaining Table II-6 (or the equivalent graphical form Figure II-9).

Table II-6

SCENARIO SHORTHAND DESCRIPTIONS

SCENARIO X (SURPRISE FREE)

1980	T_1	E_2	C_2	L_2	R_1	B_2
1985	T_1	E_3	C_2	L_2	R_1	B_2
1990	T_1	E_3	C_2	L_2	R_1	B_2
1995	T_1	E_3	C_2	L_3	R_2	B_2
2000	T_1	$\underline{E_4}$	C_2	L_3	R_2	B_2
2005	T_1	$\underline{E_5}$	C_2	L_3	R_2	B_2

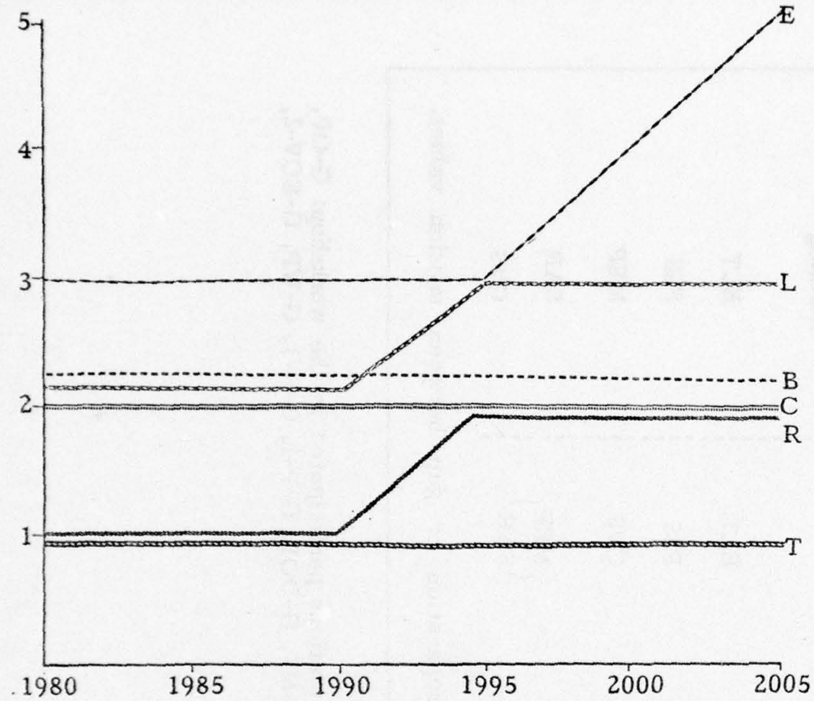
SCENARIO Y (EXTERNAL THREAT)

1980	T_1	E_2	C_2	L_2	R_1	B_2
1985	T_2	E_2	C_2	$\underline{L_3}$	R_2	B_2
1990	$\underline{T_3}$	E_2	C_2	L_2	R_2	B_3
1995	$\underline{T_3}$	E_3	C_2	L_1	R_2	B_3
2000	T_2	E_3	C_2	L_2	R_2	B_3
2005	T_1	E_3	C_2	$\underline{L_3}$	R_2	B_2

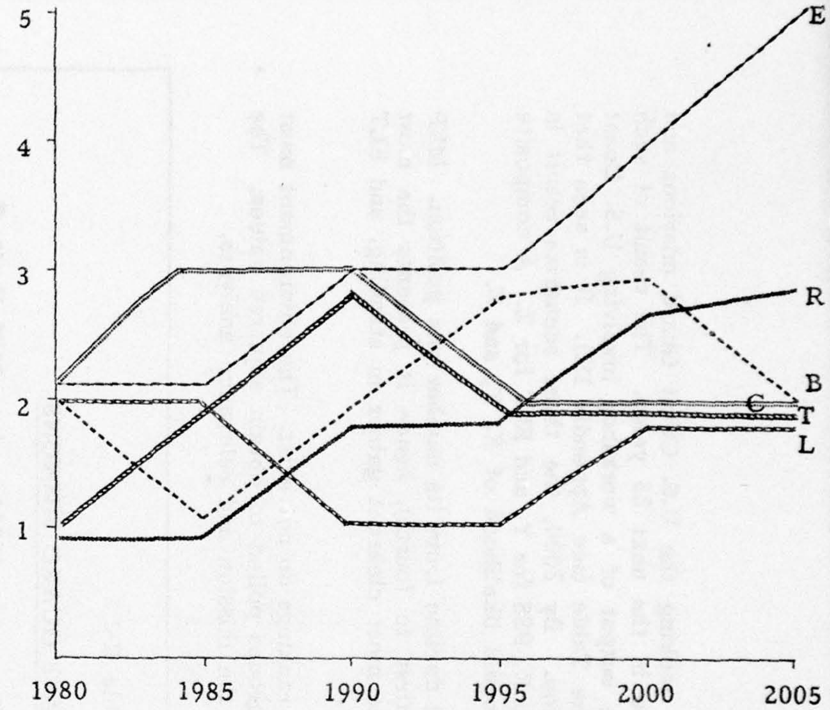
SCENARIO Z (INTERNAL SHIFTS)

1980	T_1	E_2	C_2	L_2	R_1	B_2
1985	T_2	E_2	$\underline{C_3}$	L_2	R_1	B_1
1990	$\underline{T_3}$	E_3	$\underline{C_3}$	L_1	R_2	B_2
1995	T_2	E_3	C_2	L_1	R_2	B_3
2000	T_2	E_4	C_2	L_2	$\underline{R_3}$	B_3
2005	T_2	$\underline{E_5}$	C_2	L_2	$\underline{R_3}$	B_2

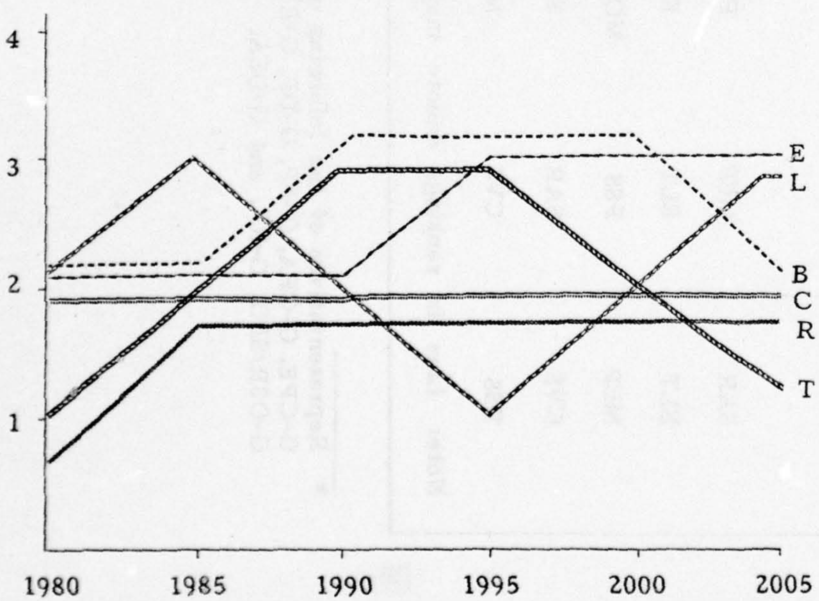
Note: the most significant changes are underlined.



SCENARIO X - SURPRISE FREE



SCENARIO Z - INTERNAL



SCENARIO Y - EXTERNAL THREAT

DIAGRAMATIC REPRESENTATION OF

SCENARIO CHARACTERISTICS.

E ENVIRONMENTAL REGULATION

L LEISURE ACTIVITIES

B USCG BUDGET

C CRIME

R MARINE RESOURCES USE

T COASTAL THREAT

FIGURE II-9

4. <u>Mission Ranking</u>

The scenarios provide a basis for ranking the U.S. Coast Guard missions and probing the potential shifts in importance in the next 25 years. The result of such an exercise is shown in Table II-7. The output of a workshop involving U.S. Coast Guard personnel* was used to develop the Table (see Appendix D2). It is seen that SAR is current by the top ranked mission. By 2000, the three scenarios result in three different rankings: MEP for Scenario X, PSS for Y, and ELT for Z. A composite ranking is also indicated; it is based on equal likelihood of X, Y, and Z.

The relative importance of SAR will decline from its number one position. MEP varies most widely over the scenarios (first to fourth), hence it presents the most difficult challenge to planning. PSS is the most clearcut gainer in standing, and ELT is never less than second in importance.

Definitive scenarios and/or mission rankings do not exist. The environment must be reviewed every few years and other groups polled to obtain adjusted values. The results of such analyses furnish input to the mission and relevance analyses.

Table II-7

RANKING OF COAST GUARD MISSIONS

1978	2000X	2000Y	2000Z	2000 X, Y, Z Composite Ranking
SAR	MEP	PSS	ELT	ELT
ELT	ELT	ELT	PSS	PSS
MEP	PSS	MO/MP	CVS	MEP
CVS	SAR	SAR	(MEP	SAR
PSS	CVS	MEP	SAR)	CVS

Note: Line in rankings denote major separation or gap between mission values.

* Representatives of the following organizations participated in the workshop: G-OP, G-CPE, G-CPA, G-BP, G-DP, G-EP, G-MP, G-DOE, G-P-1, G-R-1, G-WP, G-ECV-2, G-OSR/SEG, G-RP, and G-DSA.

REFERENCES

1. N.Y. Times, March 11, 1979, p. 1, "U.S. Finds Auto Use Threat to Economy".
2. Goeller and A. Weinberg, "The Age of Substitutability, or, What Do We Do When the Mercury Runs Out?", in H. Linstone and D. Sahal (eds.), Technological Substitution, Elsevier North Holland, New York, 1976, p. 249.
3. McHale, J. and M., "Basic Human Needs: A Framework for Action", Transaction Press, Edison, N.J., 1978."
4. Kane, J. "A Primer for a New Cross-Impact Language - KSIM", in H. A. Linstone and M. Turoff, The Delphi Method, Addison-Wesley, 1975, pp.369-382.
5. United States Department of Transportation, United States Coast Guard, Commandant's Long-Range View. (Washington: 1977).
6. Williams, C., et al., Emerging Environments, Roles, and Activities of the U.S. Coast Guard to 2000 A.D. (Alexandria: 1977).

III. MISSION ANALYSIS

The Coast Guard, a military service that in peacetime operates under the Department of Transportation, currently employs 37,000 military and 7,000 civilian personnel. In a recent DOT publication (Ref. 1), Admiral O. W. Siler, former Commandant of the Coast Guard, listed the overall purpose, objectives, and missions of the Coast Guard. These may be taken as the contextual determinants of all decisions now made that will bear fruit in future years.

The Coast Guard currently divides its activities into approximately 14 operational and 13 support missions. Operational missions serve the public directly, and support missions primarily serve other Coast Guard missions. The role of these missions can best be understood in the light of the service's overall purpose and objectives.

The purpose of the Coast Guard is "to serve, preserve, and protect our citizenry in the maritime environment". To this end, the Coast Guard functions as an operational law enforcement agency. Its purpose is accomplished through the fulfillment of seven basic objectives. These are to:

- minimize loss of life, personal injury, and property damage on, over, and under the high seas and waters subject to U. S. jurisdiction;
- facilitate water-born activity in support of national economic, scientific, defense, and social needs;
- maintain an effective, ready, armed force prepared for and immediately responsive to specific tasks in time of war or emergency;
- assure the safety and security of vessels and of ports and waterways and related facilities;
- enforce Federal laws and international agreements on and under waters, subject to the jurisdiction of the United States and on and under the high seas where authorized;
- maintain or improve the quality of the marine environment;
- cooperate with other governmental agencies and entities (Federal, State, and local) to assure efficient utilization of public resources and to carry out activities in the international sphere where appropriate in furthering national policy.

The 14 operational missions contribute directly to achieving these objectives.

In this chapter we report our analysis of the major operational programs in terms of their use of vehicles, i.e., aircraft, boats, and cutters, and other energy-related technologies. This analysis provides the basis for evaluating the importance of current and potential future technologies to the achievement of the Coast Guard's overall goals.

The mission analysis was carried out in two distinct but interrelated phases: (1) a mission flow analysis, and (2) a vehicle relevance analysis. The aim of the mission flow analysis was to examine the capabilities of current and future vehicles in the performance of Coast Guard operational tasks. In operating programs where vehicles are used, a single operation normally requires the coordination of several vehicles with different performance capabilities. To assess the viability of future fleet mixes it was necessary to see how these different capabilities are employed. This led to the development of twelve "mission flow diagrams". These display vehicles and other technologies in the context of alternative, integrated sequences of steps for some typical Coast Guard operations.The diagrams enabled us to examine vehicles, non-vehicle technologies, and alternative tactical approaches in such a way that we could assess the relevance of specific vehicles to the Coast Guard as a whole.

The thrust of the vehicle relevance analysis was to determine the adequacy and applicability of a particular set of Coast Guard vehicles to meet the general future conditions and the particular demands for services that the Coast Guard will face. The relevance-tree approach used involves a hierarchical display of programs, sub-programs, activities, and tasks. It considered each type of vehicle for its suitability in performing these tasks. "Relevance numbers", based on the mission flow analysis, were treated by a simple mathematical calculation to yield a ranking of vehicles in terms of their "importance" or "utility".

The current and projected listing of relevant Coast Guard ships and boats is shown in Appendix C and summarized in Table III-1.

The number of vehicles that are candidates for adoption by the Coast Guard in addition to the vehicles it presently has in its inventory is large. Likewise, the divergent situations that the Coast Guard faces in its present missions present an enormous range of demands on Coast Guard capabilities. These demands are examined within the shifting context of economic, political, technological, and ideological change. This broad context is presented by the scenarios in Chapter II. The relevance tree analysis derives specific applications of the scenarios to Coast Guard missions and capabilities.

Seven vehicle relevance trees were produced for this report: one for 1980 (the present), and one for each of the three scenarios in 1990 and 2005 (See Fig. II-8). The inclusion of future vehicles in future years enables the development of insights into potential future fleet mixes and the evaluation of the sensitivity of these fleet mixes to major shifts in national policy and international conditions. The following sections outline the procedures used and state the major results. This work served primarily as input to the evaluation phase of the project. The most important conclusions are restated in the final chapter of this report.

A. Mission Flow Analysis

The mission flow analysis is designed to answer the following questions: What vehicle characteristics do the mission requirements imply? What missions are performed that are crucial from the standpoint of energy conservation? What present and future vehicles may contribute to the performance of these missions? Specifically, in what ways and combinations may these vehicles be used?

TABLE III-1

SELECTED COAST GUARD VEHICLES

VEHICLE	1980	1990	2000
WMEC	23	22	13-28
WAGB Icebreaker	6	2-3	2
WHEC	18	12	3-12
WPGH Patrol Boat-Hydrofoil	1	1	0-1
PC	76	53-76	9-53
Training Cutters	1	0	0
Oceanographic Cutters	1	0	0
Buoy Tenders-Seagoing	30	0	0
Buoy Tenders-Coastal	15	5	2-5
Buoy Tenders-Inland	10	2-4	0-2
Buoy Tenders-River	18	15	0-15
Construction Tenders	14	14	5-14
Harbor Tugs	39	25	10-25
Light Ships	3	0-3	0
Reserve Training Cutter	1	1	0-1
Icebreaking Tug	1	1	1
Ships	257	153-182	45-159
Gap (based on 1980)		75-104	98-212

Note: The ranges for 1990 and 2000 indicate differences between 30 and 40 year life for ships.

This analysis proceeded through preliminary and flow analysis steps. The latter were directly related to generating the mission flow diagrams. These steps, together with the results, are described below.

1. Preliminary Steps

The preliminary steps that led up to a mission flow analysis delt with the successive refinement of our knowledge of what the Coast Guard does and how it does it. This process began with a matrix analysis of information derived from the available literature. This corresponds to the development of a tree or hierarchy with three levels: (1) program, (2) activity, and (3) vehicle.

Program/Activity Analysis

A survey of Coast Guard and DOT documents resulted in a list of fourteen major programs - SAR, ELT, MEP, etc. (MO and MP were considered separately). Next, a more extensive analysis of the same documents yielded a list of approximately one hundred activities, e.g., detect vessel. The activities were then related to the programs via a program/activity matrix as shown in Figure III-1.

An "X" in any cell of the matrix indicates the referenced activity has relevance to the indicated program. An important result was the determination of which activities are relevant to more than one program. This clarified the rationale for the multimission concept in vehicle design.

Activity/Vehicle Analysis

This step related specific Coast Guard vehicles to the one hundred activities. Each activity was examined in terms of the following:

a. Performance Standards: A list of the most important criteria for assessing a particular vehicle's appropriateness for the given activity. For example, speed, survivability, and acuity are important for search and rescue operations.

b. Activity Dimensions: A determination of the variations in activity content and/or context that might influence procedures and operational requirements, e.g., hostile versus friendly craft, or weather conditions.

c. Process Steps: An expansion of the procedural steps likely to surround and/or occur within the given activity. An ELT incident might include the sequence Detect, Locate, Identify, Pursue, and Interdict. Each process step was also identified as being one of three kinds: information-processing, planning/decision-making, and logistical/execution.

d. Vehicles: For each information-processing and logistical execution step, a determination was made of any present or likely future vehicles that would be effective. Detection might use fixed wing aircraft or lighter-than-air craft; interdiction might use helicopters or surface vehicles.

e. Non-vehicle Technology: Where appropriate, steps relating to current or likely future technology were noted. This involved information processing steps, which sometimes employ surveillance and detection instruments.

FIGURE III-1

SAMPLE PORTION OF THE PROGRAM/ACTIVITY MATRIX

PROGRAM \ ACTIVITIES	DETECT AIRCRAFT	DETECT VESSELS	DETECT SUBMERSIBLES	LOCATE AIRCRAFT	LOCATE VESSELS	LOCATE SUBMERSIBLES	INTERCEPT AIRCRAFT	INTERCEPT VESSELS	INTERCEPT SUBMERSIBLES	TRACK AIRCRAFT - HAZARDOUS CARGO	TRACK VESSELS - HAZARDOUS CARGO
SHORT RANGE AIDS											
BRIDGE ADMINISTRATION											
COMMERCIAL VESSEL SAFETY											
ENFORCEMENT OF LAWS & TREATIES	X	X	X	X	X	X	X	X	X	X	X
ICE OPERATIONS	X	X		X	X		X	X			
MARINE ENVIRONMENTAL PROTECTION	X	X	X	X	X	X	X	X	X	X	X
MILITARY OPERATIONS	X	X	X	X	X	X	X	X	X		
MILITARY PREPAREDNESS	X	X	X	X	X	X	X	X	X		
MARINE SCIENCE ACTIVITIES											
PORT SAFETY & SECURITY	X	X	X	X	X	X	X	X	X	X	X
RADIO NAVIGATION AIDS											
BOATING SAFETY		X	X		X	X		X	X		
RESERVE FORCES											
SEARCH & RESCUE	X	X	X	X	X	X	X	X	X	X	X

Figure III-2 shows how these items were organized onto a deck of notecards. Where various activities appeared to normally occur in tandem, they were regrouped into a single procedural sequence. For example, the activities Detect Vessel, Locate Vessel, and Rescue Vessel, would all occur in a single SAR operation. The hundred activities were reduced to the sixty "missions" used in the mission flow analysis.

Program Selection

Some programs were eliminated from the analysis because they consume little fuel. Among these are Bridge Administration (BA), Commercial Vessel Safety (CVS), Marine Science Activities (MSA), Radio Navigation Aids (RA), and Recreational Boating Safety (RBS).

In addition, Military Preparedness (MP) and Reserve Training (RT) have only indirect (or second order) relevance in the sense that these programs provide personnel and technical expertise in support of vehicles. In other words, it is assumed that training exercises are needed for every vehicle and mission type; hence, even though they are relevant in terms of energy consumption, a discussion of these programs here would not serve the immediate purpose of analyzing specific mission flows.

Finally, the Military Operations (MO) program is irrelevant in terms of fuel consumption. This program is implemented only in times of national emergency, during which most fuel saving measures are suspended. A discussion of situations in which fuel saving measures might become strategically significant is outside the scope of this report.

Search and Rescue (SAR), Enforcement of Laws and Treaties (ELT), Marine Environmental Protection (MEP), Ice Operations (IO), Port Safety and Security (PSS), and Short Range Aids to Navigation (AN) were the subject of detailed analysis. This analysis revealed that:

a. ELT may be split into two sub-programs: fisheries protection within the 200-mile fish conservation zone and general law enforcement along the coastlines and inland waterways.

b. IO may similarly be split into two sub-programs: one serves Department of Defense and National Science Foundation needs in the polar regions, and the other serves commercial needs in domestic regions.

c. PSS is an amalgam of MEP, ELT, and SAR, as appropriate for harbors and ports.

d. AN is one of the Coast Guard's two highest energy consuming programs.* It uses the largest number of vehicles, and it is unique from the operations point of view.

These considerations then provided the basis for the mission flow analysis.

2. Flow Analysis Steps

The mission flow analysis involved categorization of the missions into major types, development of mission flow diagrams, and application of these diagrams to stimulate discussion and draw conclusions.

---

* ELT is the other.

FIGURE III-2

SAMPLE ACTIVITY/VEHICLE CARD

#23

MISSION: Rescue Persons/Downed Aircraft

PERFORMANCE STANDARDS: Speed

DIMENSIONS: Water temperature, weather conditions

PROCESS	VEHICLE REQUIRED
Same as Rescue Persons/Vessels	Aircraft, Helicopter, Cutter Patrol Craft, MLB, MRB
1. Receive distress message	
2. Search	
3. Locate	
4. Determine operational requirements/ personnel	
5. Determine obstacles/intervening conditions	
6. Determine vehicle	
7. Travel to site	
8. Perform rescue operation	
9. Administer life support	
10. Disposition of aircraft	

Mission Types: Routine, Incident, Patrol

The main conclusion drawn from the vehicle/activity analysis was that most of the sixty missions can be grouped into one of three categories:

INCIDENT RESPONSE	- characterized by requiring an immediate sortie to deal with a situation,
PATROL	- characterized by a routine coverage of a fixed area, and
ROUTINE (other than patrol)	- characterized by standard operations carried out as needed or according to a schedule, e.g., buoy tending, or ice clearing in channels.

Incident response operations emphasize speed and durability, requiring more robust vehicles. Patrol operations emphasize range, time endurance, and acuity. Patrol operations provide:

Surveillance:	as needed for coverage of a given region,
Proximity:	availability when needed for incident response, and
Presence:	to serve as a deterrent against law violations.

Routine operations are largely problem or task-specific, requiring dedicated vehicles and technology.

A mission flow diagram is a graphic representation of the alternative methods by which a particular objective may be achieved. The project team found that, for the most part, the selected programs could be envisioned in terms of the foregoing three mission types. Patrol operations are considered to provide the logistical base for incident response operations. Because of the differences between patrol and incident response, two corresponding forms of mission flow diagrams were developed, one of these also served to describe routine operations.

Examples of these forms are discussed below. Of the twelve charts generated and listed in Figure III-3, two (3 and 10) are displayed in this section, the remainder in Appendix D1.

As suggested by the foregoing discussion, ELT and IO programs were each split into two subprograms. These are displayed in diagrams 2, 3, 5, and 6.

Diagram 7 is actually a second-order diagram. It depicts the basic components, issues, parameters, etc. relevant to any patrol operation. It served as a template for the development of each specific patrol mission diagram.

We determined that a diagram for SAR patrol was warranted, even though the Coast Guard does not conduct such patrols, except on special occasions. Diagram 8 shows what features of multimission patrols are relevant to maintaining a readiness for SAR incident response.

FIGURE III-3

LIST OF MISSION FLOW CHARTS

1. Search and Rescue - Incident Response
2. Law Enforcement: High Seas Fisheries - Incident Response
3. Law Enforcement: Coastal and Inland Waterways - Incident Response
4. Marine Environmental Protection - Oil Spill Incident Response
5. Domestic Ice Operations - Routine/Incident Response
6. Polar Ice Operations - Routine
7. General Patrol Mission Analysis
8. Search and Rescue - Patrol
9. Law Enforcement: High Seas-Fisheries - Patrol
10. Law Enforcement: Coastal and Inland Waterways - Patrol
11. Marine Environmental Protection - Patrol
12. Domestic Ice Operations - Patrol

We found that short range aids to navigation (AN) operations do not fit into either the incident response or the patrol mission flow format. This, together with the fact that it stands as one of the two leading programs in terms of annual fuel consumption (Refs. 2 and 3) motivated special examination of the AN program.

The mission flow diagrams assimilate and reorganize the information derived from the program/activity and the activity/vehicle analyses. A sample incident response mission flow diagram is Figure III-4, which was drawn up for law enforcement on coastal and inland waterways.* This diagram focuses on vehicles within the context of alternative integrated sequences of steps for carrying out a typical law enforcement task, such as boarding, issuing a citation, or performing an arrest.

Here an incident is broken down into seven steps, beginning with an initial alert and culminating in the completion of the operation. The first step, basically an information processing step, is the detection of a suspected lawbreaker. Information is received at a station or platform via one or more means of detection. The second step, surveillance-tracking-identification, is both an information processing step and a planning (or decision) step. Coast Guard personnel evaluate the situation and make initial decisions regarding response. Step three is the first stage of response. It is strictly a planning step. The appropriate stations and agencies are alerted and/or given instructions. Step four involves vehicles in some mode of transit, ranging from fast transit by air to medium-slow transit by water. The alternatives considered in this analysis include some advanced design vehicles, as shown in the boxes with dashed borders. The fifth step, interdict, is depicted as carried out by various tactical employments of vehicles. Here the possible variations of the interactions, i.e., air-to-air, air-to-surface, and surface-to-surface, are shown. The diagram also considers the possibilities of either a single vehicle acting alone or a pair of vehicles, e.g., HEC with helicopter, acting together as a team. The sixth step is devoted to physically boarding the interdicted craft, as may be required by the specific situation. The final step, return or continue, may include such tasks as returning arrested persons to a base or platform.

This diagram is typical of the various incident response diagrams. Each complete path through the diagram represents one alternative sequence of steps for mission accomplishment. Moreover, each diagram shows non-Coast Guard agencies or vehicles that might be involved, dimensions of the activity that might influence the choice of vehicles, and present or future kinds of non-vehicle technology that might influence the way an operation is initiated and/or carried out.

Finally, we may note generally that:

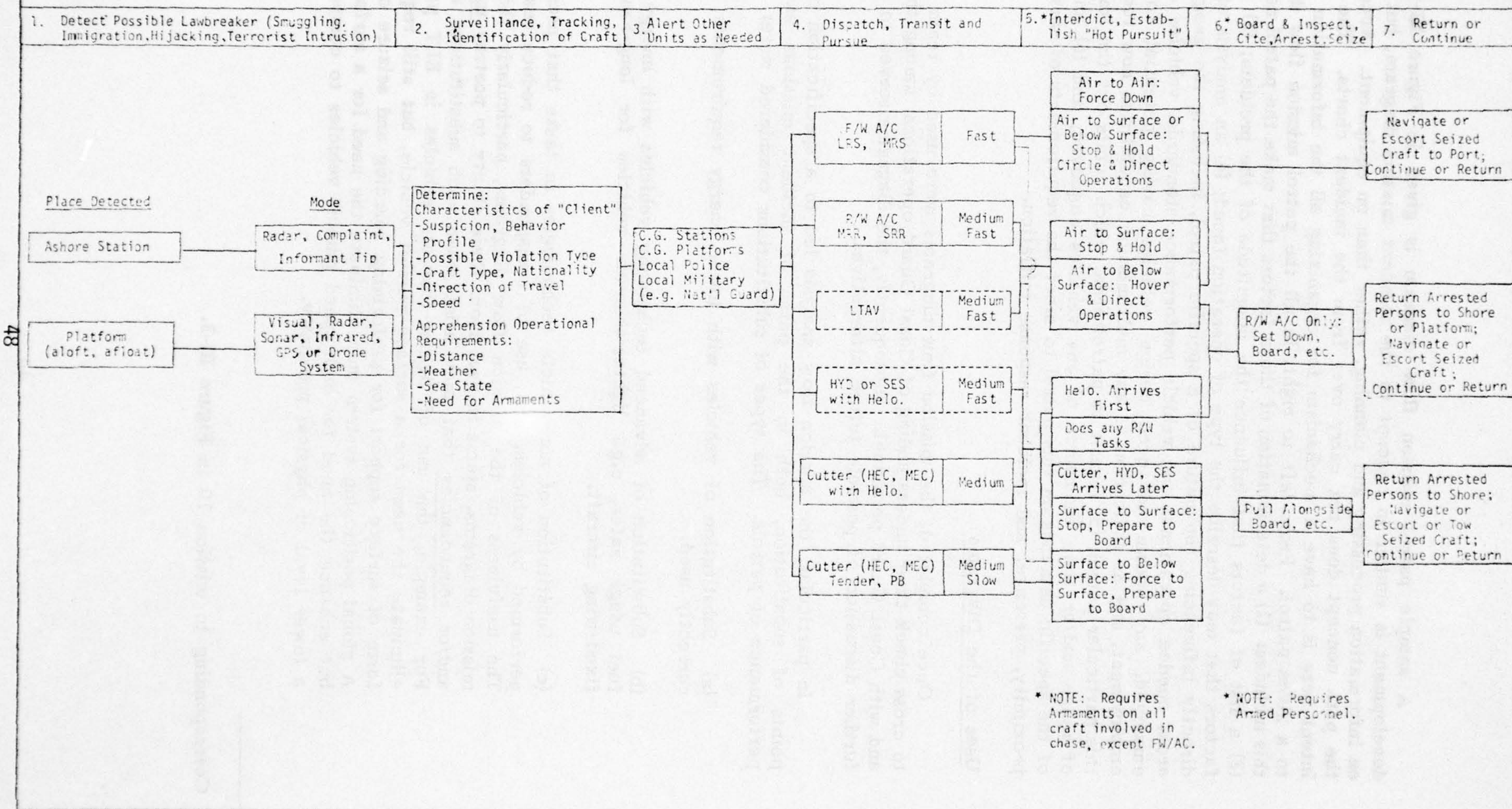
- information processing steps encompass the information source, type, mode of reception, method of processing, etc., including relevant non-vehicle equipment, e.g., GPS;
- planning or decision steps include the decision criteria, the relevant agencies, and so on;
- logistical steps include the specific vehicles and brief descriptions of how they are deployed.

---

* Corresponding to mission 3 in Figure III-3.

FIGURE III-4

#3 LAW ENFORCEMENT INCIDENT MISSION FLOW
(Coastal and Inland Waterways)



A sample patrol mission flow diagram is given in Figure III-5.* Its development is similar in concept to the incident mission diagram, but focuses on information processing and planning, rather than on equipment. Accordingly, the path concept does not carry over from the incident charts. The primary intent here is to have a mechanism for organizing all the information relevant to a given patrol. From left to right, in all the patrol mission flow diagrams, this includes: (1) a determination of those factors that make the patrol necessary; (2) a list of factors that influence the magnitude of the problem; (3) a list of factors that may describe the type of operation faced; (4) an analysis of factors directly influencing the nature of a specific patrol, including the geography of area, needed operational and vehicle performance standards, vehicles currently employed, any known advanced design vehicles having potential for future employment, and an indication of any multimission capabilities now required of this particular patrol; (5) transit to patrol area, which points out the importance of range and/or time endurance of any vehicles employed; and (6) an analysis of the specific demands on this patrol to meet the requirements of surveillance, proximity, presence, and incident response initiation.

Uses of the Diagrams

Once completed, the mission flow diagrams were used by team members to cross check their understanding of Coast Guard operations, among themselves and with Coast Guard personnel. Subsequently, the diagrams served to stimulate further discussion of possible future alternatives.

In particular, the mission flow analysis led to a specification of various points of substitution, both in the paths of incident missions and in the performance of patrols. The types of substitutions considered were:

(a) Substitution of vehicles with lower energy requirements for those currently used.

(b) Substitution of advanced technology vehicles with energy efficient fuel usage rates, e.g., lighter-than-air vehicles for long-range-search fixed-wing aircraft.

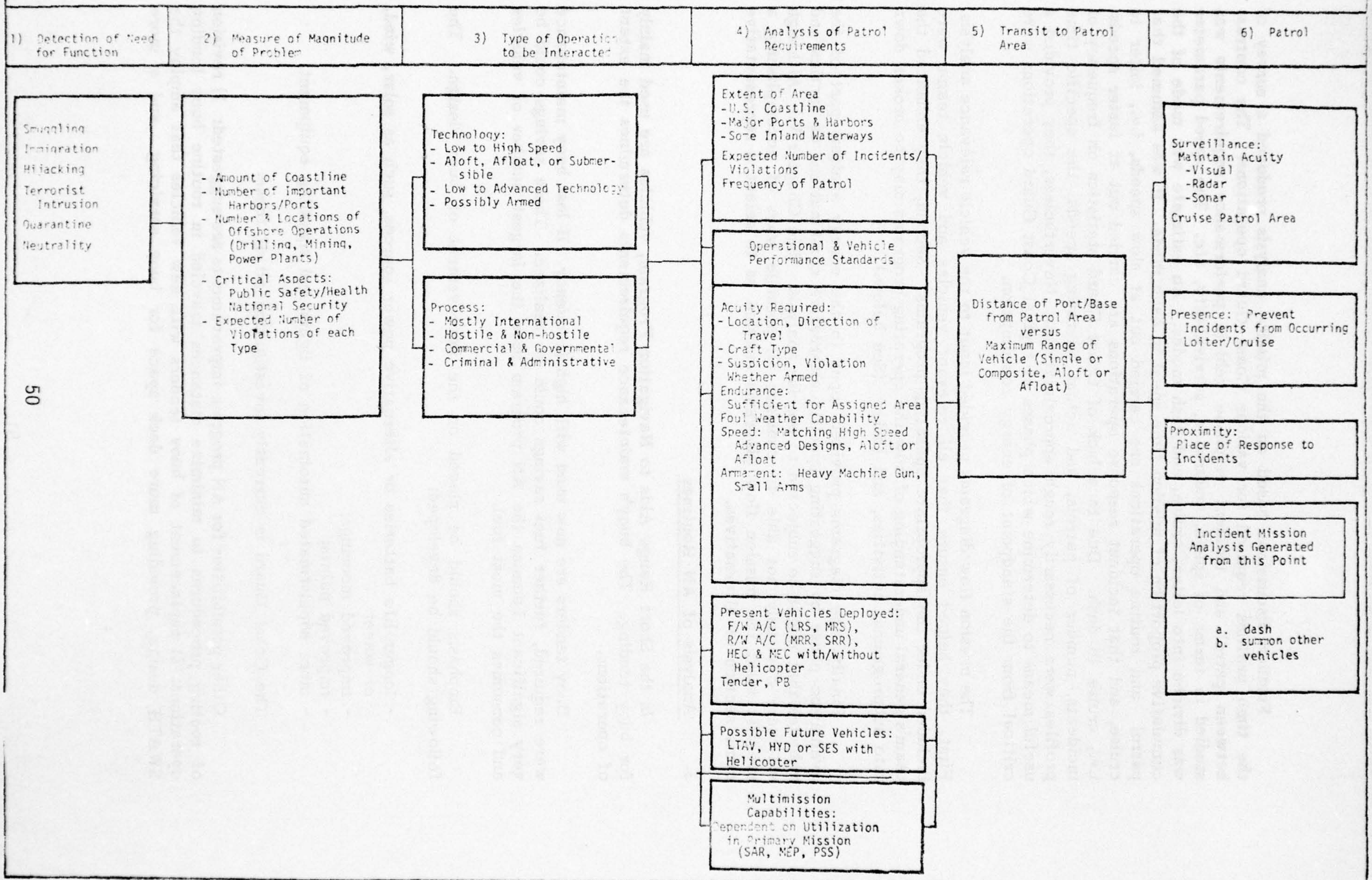
(c) Substitution of non-vehicle technologies in tasks that presently are performed by vehicles, e.g., use of transponders to reduce search time. The usefulness of the mission flow diagrams, particularly the incident mission diagrams, stems in part from their ability to portray mismatches and/or redundancies that may arise when such substitutions are made. For example, the use of lighter-than-air vehicles in ELT patrol may eliminate the need for a surface pursuit vehicle, but still require some form of surface support for performing boarding and seizure operations. A global positioning system may eliminate the need for a surface patrol, but enhance the need for high speed pursuit vehicles to compensate for a lower level of physical proximity.

---

* Corresponding to mission 10 in Figure III-3.

FIGURE III-5

#10 LAW ENFORCEMENT PATROL MISSION FLOW (COASTAL AND INLAND WATERWAYS)



Further discussions based on the mission analysis produced a survey of the time profiles required for various Coast Guard operations. The contrast between patrol and incident response vehicle performance requirements was studied in terms of speed, endurance, survivability, etc. The speed parameter was divided into loiter, cruise, and dash modes. An estimate was made of the cumulative proportion of mission time spent in each mode. It was assumed that patrol and routine operations are carried out at slow speeds, i.e., loiter to cruise, and that incident response operations are carried out at faster speeds, i.e., cruise to dash. Due to a lack of Coast Guard statistics on frequency of incidents, number of patrols, and actual operating speeds, the specific time profiles were necessarily rough approximations. Nevertheless, they provided a useful means to determine which phases of typical Coast Guard operations were critical from the standpoint of energy consumption.

The mission flow diagrams provided input to the vehicle relevance analysis. First, they helped ensure that all relevant vehicles and vehicle teams were included under the appropriate operating programs. Second, they enhanced the team's general understanding of how the operating programs may be broken down into subprograms, activities, and tasks. (See below.)

Finally, the diagrams provided input to the energy analysis part of the evaluation phase by suggesting specific alternative combinations of tactics and vehicles that might be subjected to precise analysis. (See Chapter V.) Although we were obviously not able to consider all possible ways of accomplishing a specific task, the mission flow diagrams enabled us to select a representative cross section of alternatives.

3. Analysis of AN Routines

In the Short Range Aids to Navigation Program, vehicles are used mainly for buoy tending. The buoy's maintenance requirements determines the extent of operations.

Buoy tenders are now used with high frequency. If less buoy maintenance were required, further fuel savings could be realized. These savings could be very significant because the AN program uses the largest number of vehicles and consumes the most fuel.

Emphasis should be placed on the improvement of buoy design. The following should be developed:

- longer life batteries or alternative power sources, such as solar, wind, or wave;
- improved moorings;
- improved paints;
- more sophisticated automation of lights and signaling equipment.

The Coast Guard is currently investigating all of these.

Other possibilities for AN program improvements are suggested: 1) revision of routing procedures to minimize distances traveled in routine buoy tending operations; 2) replacement of buoy tenders with new vehicles that employ the SWATH design, providing more deck space for buoy servicing and a more

stable work platform for lifting buoys from the water; and 3) optimizing the number of buoys used in each area. These items are discussed in more depth in the analysis and evaluation section of this report.

4. Results

The mission flow analysis produced several interesting results regarding (a) the interplay between incident response and patrol operations and (b) the benefits of multimission versus dedicated vessels. It also provided a basis for studying the viability of new vehicle designs and/or the implementation of new non-vehicle technologies.

Incident Response vs. Patrol

Incident response and patrol operations differ substantially in their vehicle performance requirements. Incident response operations typically require speed and durability. Patrol operations require endurance (time and/or distance) and acuity (visual or electronic). Because patrol operations generally serve as logistical bases for incident response, the design of vehicles serving both functions must be a compromise.

A second contrast appears between surface patrols and aerial patrols. The basic functions of a patrol operation have been analyzed in terms of surveillance, proximity, and presence. Aerial patrols are, in many cases, better for surveillance, since, with better acuity and higher speeds, they provide more area coverage per unit time; but they cannot provide an adequate physical presence, since aircraft time endurance is very low. Since proximity is important only for incident response and requires either a surface vehicle or the ability of the aircraft to set down on water, aircraft are of only limited relevance in terms of proximity. This explains why a cutter-helicopter team provides a good patrol operation. The helicopter brings superior performance for surveillance needs, and fulfills partial needs of proximity, and the cutter provides both proximity and presence. In terms of performance characteristics, therefore, this team offers a good all-around combination of speed and acuity (via the helicopter) and endurance and survivability (via the cutter).

This analysis, in turn, provided a template for considering new possibilities for advanced design vehicle substitutions. The SWATHS is a possible replacement for the conventional cutter in the cutter-helicopter team. A possible energy-saving combination would be the lighter-than-air craft operating in conjunction with a 95' patrol boat or hydrofoil.

The distinction between incident response and patrol operations also provides a way of looking at advanced surveillance technologies. The salient question here concerns the viability of sophisticated surveillance systems, such as those employed by drone aircraft or in satellites. If such systems were widely implemented, what vehicles would be either relevant or required? A remote sensing system would clearly obviate the need for many patrols, but what would replace the patrol function insofar as it provides proximity for incident response? A working hypothesis is that the needed incident response capabilities could be provided by high performance advanced design vehicles. In terms of energy conservation, this translates into the question of whether the

energy saved by eliminating extensive surface and manned aerial patrols would be great enough to justify the additional energy expense of high performance surface craft. The answers to these questions depend ultimately on obtaining current and projected statistics for frequency of incidents versus time on patrol. At present, the Coast Guard data collection systems do not provide the needed detail.

Multimission Vehicles versus Dedicated Vehicles

The fact that patrols serve as a basis for incident response operations appears to be the nexus of the multimission concept in cutter design. When it is necessary to have a patrol vehicle in service over a certain area, it makes sense to have that vehicle serve the patrol needs of several programs simultaneously. It follows that the same vehicles, inasmuch as they also provide proximity to incidents, should be equipped and staffed to respond to incidents under the same assortment of programs. The programs most often entering into these considerations are ELT, PSS, MEP and SAR. Moreover, MO/MP needs must be met whenever the vehicle may be expected to respond in time of national emergency.

The outfitting and staffing of patrol vehicles for multimission incident response points to a trade-off between operational efficiency in patrol versus efficiency of response. Historically, the needs of the specific programs have been such that it has been possible to design satisfactorily effective vehicles within these constraints. However, as these programs evolve toward greater complexity, increasing the variety of response capabilities becomes more problematic. At some point, the capability of responding to incidents of one type will impinge on the capacity to respond to those of another. At that point, the possibility of moving toward dedicated patrol and/or response vehicles deserves consideration.

The ports and waterways boat is a good example. As the needs of serving ports and harbors became more complex, it became desirable to have a boat of the appropriate size, and carrying the appropriate equipment, e.g., special fire fighting equipment. Thus, the ports and waterways boat was developed.

The same issue takes on a somewhat different flavor in the context of advanced electronic surveillance technologies, especially with respect to coastal and high seas ELT, MEP, and SAR operations. If a satellite or drone system were to be implemented, then the idea of dedicated incident response vehicles becomes tenable.

The implementation of such a system would reduce the need for surface patrols to provide surveillance, but the elimination of surface patrols would be detrimental to the needs of proximity and presence. However, the fuel consumed by patrols could be diverted to high performance vehicles specially designed for incident response. These vehicles could be either kept at a shore station or deployed sparingly for patrols. Their principal use would be in incident response.

From a mission analysis standpoint, therefore, this approach seems workable. The remote sensor system provides surveillance; the need for physical proximity is obviated by the use of high performance response vehicles; and, if the Coast Guard develops a reputation for fast response to law violations, the need for presence is also eliminated.

From an energy analysis standpoint, the question of viability hinges on whether or not the fuel savings from patrol reduction would offset the cost of operating high performance response vehicles. The most important consideration involved is the expected frequency of incidents. The concept of single program mission response vehicles becomes more reasonable within the context of a remote surveillance system. For example, escalating concern for the environment may warrant having vehicles designed specifically for MEP duties. These and other considerations emphasize the need for careful analysis of the basic assumptions now underlying current Coast Guard approaches to vehicle selection and design.

B. Vehicle Relevance Analysis

The vehicle relevance analysis is designed to answer two interrelated questions. What is the importance of each vehicle to the performance of Coast Guard missions? Which set of vehicles gives the Coast Guard the maximum capability to perform future tasks?

To answer these questions, it is necessary to determine the general conditions and particular demands for services that the Coast Guard will face in the future. This determination has been embodied in the three scenarios presented in Chapter II.

The vehicle relevance analysis, using a relevance tree approach, interprets the three scenarios in terms of the fleet mixes needed to meet anticipated future demands. The vehicle relevance analysis also integrates the projected availability dates for advanced design vehicles.

This led to the development of seven distinct trees: one for 1980 and one for each of the three scenarios in each of the years 1990 and 2005 (see Fig. II-8).

1. Relevance Trees

The relevance tree analysis used here was based on a hierarchical analysis of overall Coast Guard operations. Finer and finer levels of activity were defined down to a bottom level of activities or tasks that may be performed by specific fleet vehicles or vehicle teams. This analysis of operations by levels of activity was a straightforward derivative of the mission flow analysis. It provides a perspective on the relation of vehicles to Coast Guard operations.

The Basic Analytical Structure

Every relevance tree in this analysis has the same basic components.

Level 1: Overall Coast Guard Operations. A single, top-level element representing the total Coast Guard function.

Level 2: Operating Programs. Ten operating programs, such as SAR, ELT, and MEP were selected from the original list of 14, and one possible emergent program was projected on the basis of Scenario Z. These constitute all the specific programs deemed to be relevant from the standpoint of vehicles.

Level 3: Sub-programs. The mission flow analysis suggested a division of certain programs into smaller parts. Among these were:

ELT - High Seas Fisheries
Coastal and Inland Waterways
IO - Polar Operations
Domestic Operations
MO/MP - Military Operations
Military Preparedness

Level 3A: Further Regional Breakdowns. The IO Program was further divided into geographical areas of operations, e.g., Great Lakes and Alaskan Coast.

Level 4: Activities. Each program or sub-program may be considered a collection of activities. Certain of these utilize vehicles, and others are administrative. For the programs explicitly studied in the mission flow analysis, the typical activities are routine operations, patrol, and incident response. When administrative activities form a significant part of a program or subprogram this is indicated in the tree.

Level 5: Tasks. Certain activities are further broken down into tasks and others are not. For example, in SAR, the incident response activity is divided into search and rescue. On the other hand, the patrol activity is not further subdivided. It is regarded as a primary task. Each relevance tree contains about 40 such tasks and activities. These are the finest grained levels of "operations" analysis, whereas the next lower and final levels consider specific items of hardware.

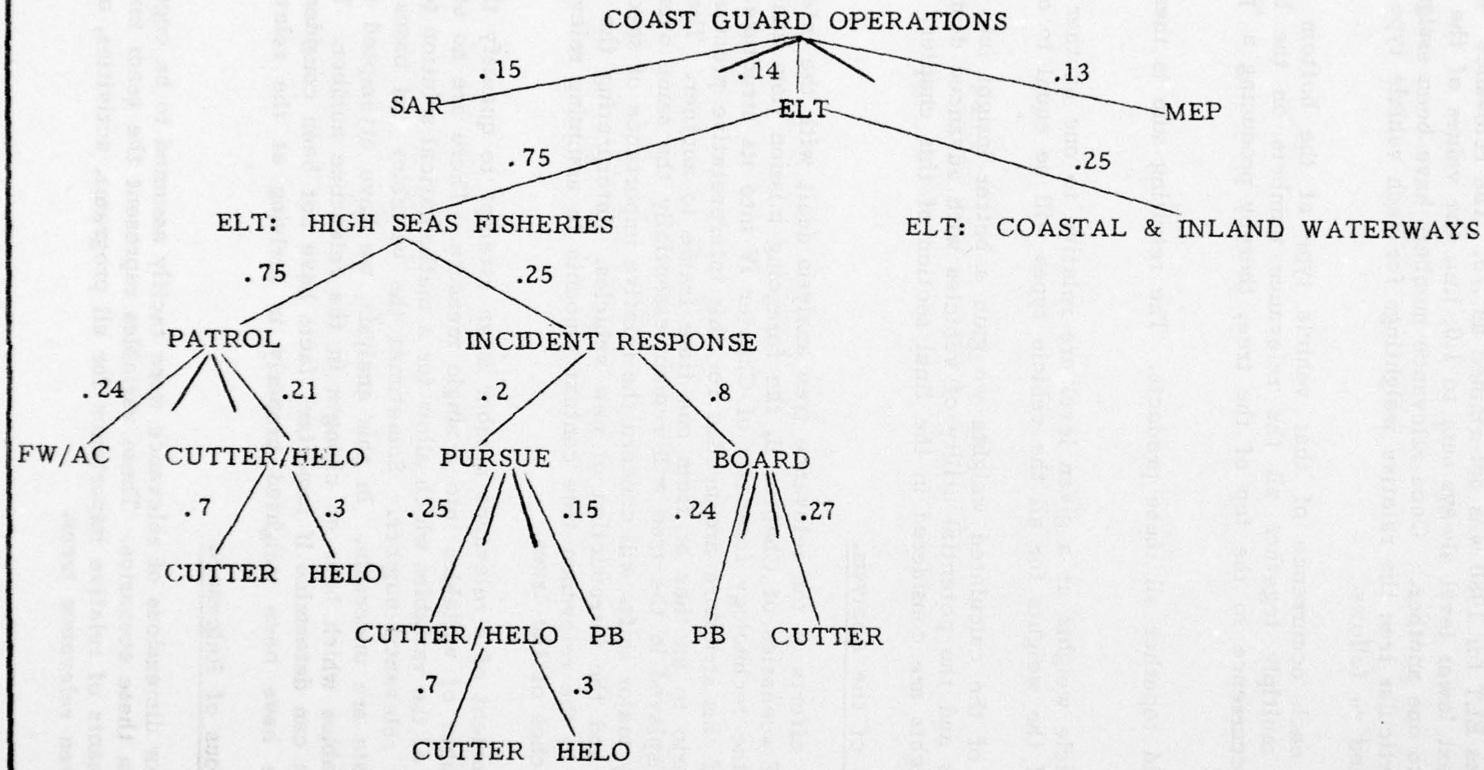
Level 6: Vehicles and Vehicle Teams. Each primary activity or task was compared to a list of vehicles and vehicle teams appropriate to the time frame of the particular relevance tree. In accordance with the technology forecast presented in Chapter IV, there are two such vehicle lists: one for 1980 and one for 1990 and 2005. Typical vehicle types are fixed-wing aircraft, high-endurance and medium-endurance cutters, and medium-sized hydrofoils. Typical vehicle teams are the cutter/helicopter combination and the SWATH ship/helicopter combination. The 1980 list contains 25 items, and the 1990-2005 list contains 34 items.

Level 6A: Team Components. Where any Level 6 item is a vehicle team, there is one further level. It considers the team members separately.

The following sections discuss in more detail the specific items appearing in various levels of relevance trees in more detail. Some typical branches of the 1980 relevance tree are shown in Figure III-6. By definition, a branch is a single continuous path from any one vehicle up through the tree to the top. A specified position at each level of the branch is called a node.

FIGURE III-6

TYPICAL SEGMENT OF THE 1980 RELEVANCE TREE



NOTE: ONLY SOME BRANCHES ARE SHOWN

Mathematics of the Relevance Tree Analysis

The numbers on the figure are relevance numbers, representing subjective evaluations by the Project Team as to the relevance of the item at each node of the tree to the item at the next higher node, e.g., the relevance of patrol operations to high seas fisheries ELT for 1980 was determined as .75. The relevance values linking a node to the next lower level always sum to 1.0, i.e., the values of the linkages are always relative to one another. Once relevance numbers have been assigned to every segment of a particular tree the relative weightings for each vehicle type in that tree can be determined as follows:

First, for each occurrence of that vehicle type at the bottom level of the relevance tree, multiply together all the relevance numbers on the branch which connects that occurrence to the top of the tree, thereby producing a "product" for that occurrence.

Second, add together all these products. The resulting sum is then the desired weight.

These vehicle weights at a given level are relative to one another in the sense that the sum of the weights for all the vehicle types will be equal to one.

By virtue of the calculated weights we gain a better insight into the need for current vehicles and the potential utility of vehicles with advanced designs. Various uses of the weights are considered in the final section of this chapter.

2. Components of the Analysis.

The major *efforts of the* relevance tree analysis dealt with the interpretation of the X, Y, and Z scenarios of Chapter II, the foregoing mission flow analysis, and the integration of the technology forecasts of Chapter IV into its structure. Only slight modifications of this structure are needed for this interpretative process as we move from one scenario to another or from one time frame to another. The structure of operations as displayed in the tree will remain essentially the same over the next 25 years. The only major shifts will concern the relative importance of specific programs and activities, and the introduction of new vehicles. Interpreting the various items of information in the relevance tree context amounts to assigning relevance numbers to all the branches of the trees.

The assignment of a relevance number is an attempt to quantify the interaction of a large number of variables into a single measure. There are no strict rules for the interaction of the variables which allow for a mathematical solution to the question of the correct relevance number. Sometimes the variables and bases for assigning different weights are uncertain. In this analysis, we have attempted to specify the important variables which bear on changes in the relevance number. Thus, the user of the research can determine if important facts have not been considered and if the facts available have been weighted properly in arriving at the relevance number.

Major Dimensions of Relevance

Four major dimensions of relevance were tacitly assumed to be cogent throughout all situations in these scenarios. These variables represent the team insights into the broad determinants of relative importance for all programs, activities, and vehicles in any of the seven relevance trees.

Resource Use

As might be expected, the size of a program or mission of the Coast Guard will influence the relevance numbers. A program or mission with large amounts of personnel and resources will tend to receive a high importance value. The Aids to Navigation program is perhaps the most prominent example of a program that is assigned a relevance number that is heavily influenced by the sheer magnitude of personnel, vehicles, and fuel use required for the program. It must be stressed, moreover, that the dimension "resource use" pertains specifically to the team's understanding of how Coast Guard personnel rated their own programs during presentation of the project Interim Report, i.e., in terms of both cost and need. The other three dimensions refer only to needs as is consistent with the general intent of mission analysis.

Prominence of Programs in Coast Guard

Certain Coast Guard programs are very prominent in the mind of the public, Coast Guard clientele, and governmental bodies that determine policy and budget. The Search and Rescue program is the best example of this. It is the one program that defines the image of the Coast Guard. Its actual resource use and personnel dedicated to the performance of the missions is relatively small, yet the program receives a high relevance number. In part, this is a result of the prominence of the mission. It is also the result of the high cost stipulated for the loss of life and property value that would result in the failure to maintain adequate capabilities and performance of this mission.

Policy of Coast Guard

The Coast Guard of itself emphasizes certain roles that it defines for itself, are mandated, or have developed as a historical role for the service. It is a matter of judgment of the research team which roles will receive the discretionary emphasis that is the inherent authority of Coast Guard leadership.

The Coast Guard has general mandates for performance in many areas. The question of which of the individual programs is emphasized is one that is addressed in the relevance tree. We have made interpretations of a likely emphasis, e.g., of enforcement of laws and treaties with regard to smuggling and terrorist activities versus increased attention to marine environmental protection. Both of these areas appear to present increasing problems to the Coast Guard. Which of them or (others) receives the emphasis beyond the mandated level is a dimension of interpretation which has been integrated into the relevance analysis.

Contribution to Performance or Contribution to Task Capability

This dimension is already implicit in the concept of a relevance number. The relevance tree structure has been shown as one of successive branching from a broader to a narrower focus. The contribution of each item to the immediately higher goal or task is defined quantitatively by the relevance number.

Scenario Interpretation

The X, Y, and Z scenarios were defined in terms of six major dimensions, each of which has a different time contour describing its relative strength over the period 1980 to 2005 (Figure II-9). The six dimensions are: (1) coastal threat, (2) marine resource use, (3) environmental regulation, (4) crime relating to coastal and inland waterways use, (5) marine related leisure activities, and (6) Coast Guard budget.

These dimensions are interrelated and describe an integrated situation at a particular point in time. For example, under Scenario Y the dominant dimension is the external threat of warfare. In keeping with this dominant dimension the budget of the Coast Guard is increased and marine related leisure activity is decreased in 1995.

If the scenarios lead only to minor changes in the order of importance of vehicles under the widely divergent conditions they portray, then the Coast Guard has some assurance that its decision making on vehicles is relatively insensitive to broad shifts in national and international conditions. As may be seen in the following, this is actually the case, i.e., the order of importance of vehicles is reasonably stable across all three scenarios.

<u>Assembly of Set of Vehicles</u>

Vehicles used and potentially used by the Coast Guard have been considered in other parts of this project, particularly the mission analysis and technology survey. Numerous discussions and informal meetings among team members produced a set of vehicles which covers the scope of relevance to Coast Guard missions.

The vehicle set was assembled to meet the following requirements:

(a) A standard set for all scenarios.

(b) Comprehensive: able to cover the range of present and future missions.

(c) Germane to the analysis: not unduly large, and containing no vehicles which are a priori trivial.

(d) Known to be technologically available.

These requirements are discussed below.

(a) Standard set for all scenarios.

To be certain that the possible application of a vehicle has been included in situations where its a priori utility appears remote, the total set of vehicles needs to be assessed under all scenarios. It may be discovered under this process that a particular vehicle which initially appeared to be specialized for a single mission or a small set of missions, is particularly robust, i.e., capable of serving a wider variety of needs. We also wish to utilize the analysis to discover whether there are novel applications of vehicles which might have been overlooked without this analysis.

(b) Comprehensive.

Assurance is necessary that every vehicle with possible application to Coast Guard missions has been assessed. There are two major aspects to this dimension:

(1) Present technology vehicles not currently in Coast Guard inventory.

It appears that there are distinct gaps in the application of present vehicle technology to Coast Guard missions. The project team has sought to fill these gaps by consideration of (1) a heavy lift helicopter called the SKYCRANE, (2) an intermediate capacity fixed wing aircraft with payload in the range of 1,000 to 2,000 lb. (4 to 6 persons), referred to here as the CESSNA, and (3) two sizes of submarines, one capable of carrying a typical crew, and one very small one-man submarine.

(2) Advanced Technology Vehicles: Surface Effect Ship, SWATH ship, Planing Craft, etc.

(c) Germane to the analysis.

We wished to eliminate vehicles of little importance. Some vehicles have limited applications to Coast Guard activities, e.g., land vehicles. For others, there is little of significance to be said about their limited capabilities or technological development, such as a skiff. For others, such as the executive personnel transport, the area of application is determined by policy outside of the area of inquiry of this study.

(d) Technologically Available.

This concerns advanced technology vehicles. Assurance is necessary that a particular vehicle concept is actually feasible and that the vehicle will be available at a stage of development that allows the Coast Guard to make a realistic decision on its deployment. Vehicle availability dates were therefore crucial in this analysis.

Relevance Number Assignments and Calculations

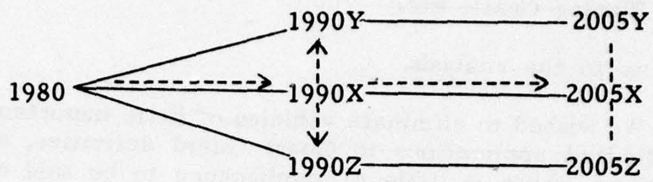
Development of the seven relevance trees followed a pattern which was based on the team's interpretation of the three scenarios of Chapter II. This pattern is depicted by the dotted lines in figure III-7. The major initial effort went into creating the 1980 tree which served as a prototype for the remaining six trees, and was a common starting point for all three scenarios X, Y, and Z. We next developed 1990 and 2005 trees along the pathway envisioned in the surprise-free future of scenario X. These two trees then served as the bases, respectively, for developing 1990 and 2005 relevance trees for scenarios Y and Z.

This procedure facilitates seeing the future in two ways. First, the development of the scenario X trees enables us to see how future Coast Guard fleet vehicle needs evolve from the present. Second, the creation of 1990 and 2005 trees for scenarios Y and Z permits a cross-comparison of the impact on fleet vehicle needs of broad fluctuations in national and international conditions.

Assignment of specific relevance numbers for the trees makes use of several different sets of criteria and sources of information, depending primarily on the level at which the assignment is to be made. A brief procedural description by level of relevance is presented in Appendix D2. Finally, the procedure for calculating importance numbers for the vehicles is outlined in Appendix D3.

FIGURE III-7

DEVELOPMENT OF THE SEVEN RELEVANCE TREES



3. Results

The final calculations for the seven relevance trees provided seven lists of weightings that measure the relative importance or usefulness of vehicles to the overall performance of Coast Guard operations. Each list reflects the assumptions of the scenarios and the time frame of the particular tree. These weights can be used for further interpretations and inferences.

Rank Orderings

The vehicle weights were first used to produce seven rank orderings of vehicles, from best to worst, with respect to overall operations. The six future lists could then be placed side-by-side with the 1980 list to see how the relative importance of vehicles might change with time. The top portions of these lists are shown in Figures III-8 and III-9 (more complete lists are presented in Appendix D, pages D-20 and D-21). Figure III-8 compares the 1990 lists for scenarios X, Y, and Z to the 1980 list, and Figure III-9 makes a similar comparison for the 2005 lists. The same information contained in these lists may also be reorganized as shown in Figure III-10. This figure focuses on individual vehicles and shows the position of each vehicle group in each of the seven lists.

There is a striking similarity in all these lists. Aircraft rank notably high throughout. The helicopter is the most useful vehicle in the current fleet and is likely to remain so for the next 25 years. The helicopter is applicable in a very wide spectrum of activities and tasks. It also participates in a variety of current and future vehicle teams. Helicopters are now carried aboard many cutters and icebreakers, and might be used on future vehicles of advanced design.

Aircraft generally were ranked high because of their suitability for patrols and capacity for quick response. Good acuity for surveillance plus a high speed capability are essential to many current and future Coast Guard operations.

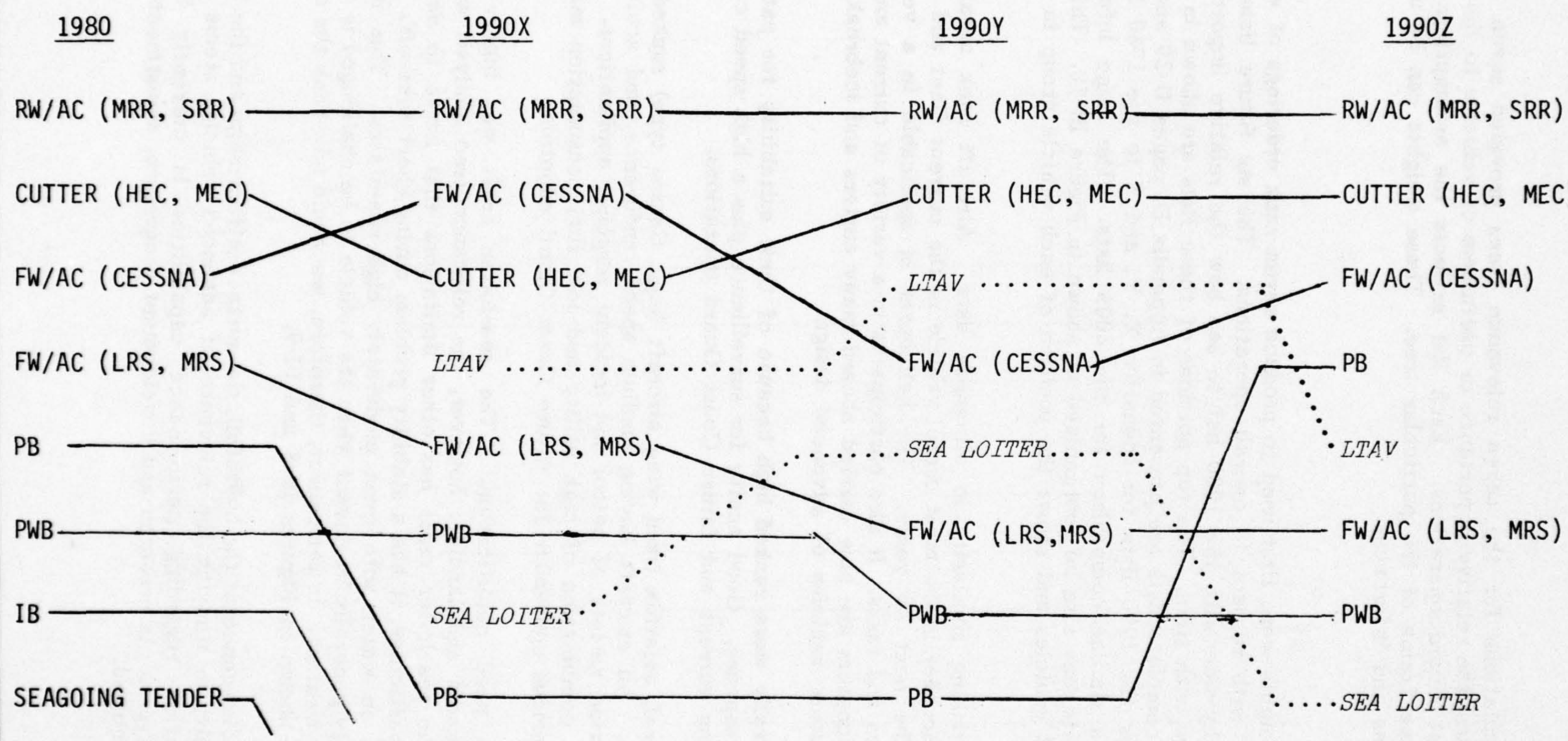
A light, general, aviation fixed wing aircraft (e.g., Cessna type) ranked high in potential usefulness. An aircraft having medium speed, endurance, and acuity would be adequate for a wide variety of patrol and incident response applications. As may be seen below, the combination of high utility and low fuel consumption makes this kind of vehicle a serious contender for future Coast Guard adoption.

Three points need qualification. The sea-loiter craft was higher in fuel consumption for takeoff and landing; however, the relevance tree analysis was based only on utility. The sea-loiter craft has other limitations that serve to devalue its general utility. In particular, it has a stability problem during short take-off. Further, it cannot set down on water with even moderately high sea-states. This makes its "sea-loiter" capability generally irrelevant when the vehicle to be challenged is operating in moderately rough weather. In retrospect, therefore, we would now rank the sea-loiter craft lower than is shown in Figures III-8 and III-9.

The second point concerns the hydrofoil, the surface-effect-ship, and the SWATHS. The primary difficulty in studying the relevance of advanced vehicles stems from the fact that information regarding performance capabilities is currently based on experimental prototypes. As research and development progresses, adjustments in their rankings will be required.

FIGURE III-8

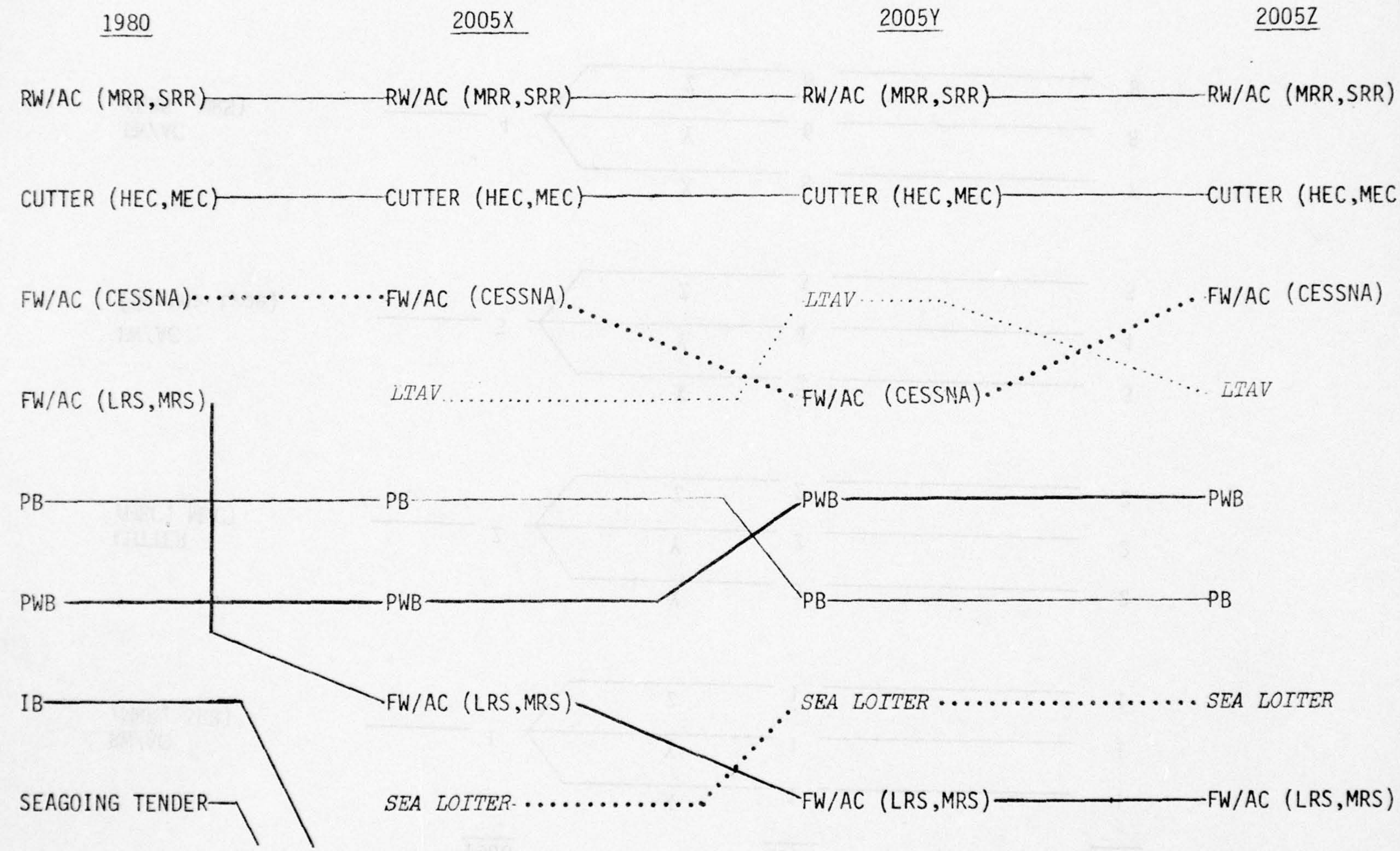
VEHICLE RANKING BY IMPORTANCE, 1980 VS. 1990



VEHICLES IN ITALICS ARE AVAILABLE IN 1990 BUT NOT IN 1980

FIGURE III-9

VEHICLE RANKING BY IMPORTANCE, 1980 VS. 2005



VEHICLES IN ITALICS ARE AVAILABLE IN 2005 BUT NOT IN 1980

FIGURE III-10

VEHICLES BY POSITION IN IMPORTANCE RANKING LISTS

	1980		1990	2005
RW/AC (MRR, SRR)	1	X	1	1
		Y	1	1
		Z	1	1
CUTTER (HEC, MEC)	2	X	3	2
		Y	2	2
		Z	2	2
FW/AC (Cessna type)	3	X	2	3
		Y	4	4
		Z	3	3
FW/AC (LRS, MRS)	4	X	5	7
		Y	6	8
		Z	6	8
LTAV	Advanced	X	4	4
		Y	3	3
		Z	5	4

The third point is that because advanced design vehicles are unconventional in nature, certain important advantages of them can be overlooked. The hydrofoil tended to be regarded primarily as a high performance vehicle, with operating speeds around 50 knots and a length of 100 to 150 feet. Some important facts were downplayed. First, the hydrofoil design feature is implementable for a wide range of conventional ships, from small 40' craft to large 378' craft. Second, because the hydrofoil is operable as a displacement vessel, it shares most of the performance capabilities of conventional cutters. This makes the hydrofoil appear like a cutter with the added capability for high speed performance. Therefore, the hydrofoil can be considered more versatile than first assumed. This would lead to higher relevance rankings.

The surface-effect ship was originally devalued because of its low survivability in rough seas. However, large surface-effect ships may be very survivable. The prototype size might not be indicative. Moreover, a positive advantage of the surface-effect ship not considered is its very large deck space, which allows it to carry more equipment than the conventional cutter. For the SWATH ship also, the importance of a large deck was not considered. A further pass through the relevance analysis could rank the SWATH ship generally above the conventional cutter.

However, these qualifications only alter details. The important general conclusions remain unchanged. These general results are discussed below.

Sensitivity of Relevances to National Stress

The usefulness/importance of the various vehicles remains substantially unchanged over time, regardless of large shifts in national and international conditions. The rank orderings of vehicles are similar throughout all seven relevance trees. The relative values of specific vehicles to overall Coast Guard operations are insensitive to the varying importance assigned to the operating programs.

This result could be anticipated by examining the occurrences of vehicles in the relevance trees. Much of the Coast Guard fleet consists of multipurpose vehicles. The same vehicles tend to appear in all of the same operating programs. These programs have been consistently ranked high in importance, regardless of external conditions. For example, except in the severest national emergencies, ELT and MEP operations are of high importance.

The general conclusions may be corroborated by examining the seven lists in the context of the scenarios. The Y and Z scenarios depict wide fluctuations in national stress during a period around 1990, with subsequent return to approximately normal situations around 2005. Accordingly, the 1990 lists have vehicles dedicated to AN and IO ranked slightly lower than in 1980 and 2005. However, such deviations may be regarded as slight. Throughout the seven lists, the dominant vehicles clearly remain dominant and the lesser ones remain less significant. The perceptible fluctuations are generally confined to rearrangements of the same vehicles within each category of dedication.

This conclusion was confirmed by an exercise using some weights developed by Cetron for Coast Guard objectives (Ref 4). Eight objectives were determined to belong logically to a relevance tree level intermediate between the top of the tree and the level of operating programs. The eight objectives, with the Cetron weights, were inserted into the 1980 tree. The relevances of programs to objectives were estimated, and the weights of vehicles with respect to overall Coast Guard operations recalculated. No significant difference in the relative vehicle weights was found.

Finally, this relevance tree analysis does not address the numbers of vehicles needed in a future fleet mix. For example, the fact that the buoy tenders now comprise a major portion of the fleet is not reflected in the 1980 tree. This type of data cannot be derived from the trees. The relevance tree approach focuses only on the usefulness and/or importance of vehicles, not on their numbers.

Non-vehicle Technologies

The vehicle relevance analysis did not include any assumptions concerning improvements in non-vehicle technologies, such as shipboard computers or electronic surveillance systems. This approach was adopted to prevent the analysis from becoming too complex.

Regarding electronic surveillance systems, the relevance tree analysis would reiterate the conclusions drawn in the mission flow analysis. That analysis noted: (1) as the specific needs of various missions increase in complexity, the multimission concept in single vehicle design becomes less viable; and (2) in the context of electronic surveillance systems, multimission vehicles become less necessary, being perhaps more advantageously replaced by dedicated mission-specific vehicles with high performance capabilities. Thus, in a relevance analysis which assumes a context including such advanced systems, one would expect to have the high performance advanced design vehicles ranked higher than they are here.

REFERENCES

1. "The U.S. Coast Guard: Its Missions and Objectives", Department of Transportation, USGPO, 1977.
2. Tetra Tech Inc., "U.S. Coast Guard Energy R&D Program Plan", Vols. I and II, Reports Prepared for U.S.C.G., August, 1975.
3. Communication from U.S. Coast Guard, Chief, Plans and Programs Staff, G-OP/74, 4101, Aug. 31, 1979.
4. Cetron, M.J., et al., An Analysis of the Relevant Factors and Events Affecting U.S. Offshore Management and Security in the 200-Mile Zone. Ocean Operations Division, U.S. Coast Guard, Washington, D.C.

IV. TECHNOLOGY FORECASTS

A. Introduction

Current projections and studies of energy indicate significant changes in the future price and availability of all energy forms, particularly petroleum products (natural gas, coal, and electricity). The potential impact of non-conventional energy technologies, such as solar and wind, remains uncertain. Since the Coast Guard is heavily dependent on petroleum products (e.g., diesel, jet fuel, aviation gasoline), our study addresses not only the questions related to low-energy vehicles (LEV) per se, but also examines a diverse set of options which can significantly reduce or shift the Coast Guard's dependence on petroleum products. Such options include the possible use of alternate fuels and energy technologies, as well as non-vehicle technologies and systems if and when they become available.

Current, promising research indicates that it may be possible for the Coast Guard to switch to alternate fuels derived from domestically abundant resources such as coal and renewable resources (e.g., biomass) since they will be available in substantial quantities by 2005. In South Africa, for example, a significant portion of the domestic demand for gasoline is already being satisfied by converting coal into synthetic gasoline. Energy technologies, such as solar and photovoltaic cells, could also provide more reliable power sources for remotely located sensors, buoys and platforms.

The future also holds possibilities for improvement in the energy efficiency of existing vehicles by improved design of propulsion systems and operations. For example, the FAA (Federal Aviation Administration) has reported savings of up to 10% in jet fuel consumed by commercial aircraft, by utilizing more efficient take-off patterns and flight paths. The energy efficiency of autos and trucks is being improved by reducing their weight.

The development of new vehicles and technologies by the U.S. Navy and the Coast Guard are likely to affect the Coast Guard's future energy requirements. However, the design of many advanced/new vehicles is intended to improve their performance (e.g., greater speed, larger payloads, increased range) and may not lower their energy consumption.

Improved and advanced navigation, communication and control systems are examples of non-vehicular technologies which could reduce energy consumption by reducing vehicle use. As an example, a video communication system could eliminate the need for transportation. Ship identification through the use of sensors and pattern recognition techniques would reduce search times.

B. Low Energy Setting: Technological Options

The alternate means of reducing Coast Guard energy requirements are graphically structured in Figure IV-1, and are labeled as the Low Energy Setting (LES).

Each component of the LES morphology shown in Figure IV-1 consists of several technological options. We therefore briefly describe the salient characteristics of each component so that technologies which are significant in terms of an energy perspective can be identified and become candidates for technology forecasts.

1. Vehicle Technologies

(a) Low Energy Technologies for Existing and Near-term Vehicles

The performance and design characteristics of existing and most near-term vehicles are documented in the literature and are not described here. (e.g., see refs. 20, 47). The focus is on technologies capable of lowering the energy requirements of these vehicles. Other types of technologies (e.g., navigation) used in a vehicle are not considered.

Technologies which can reduce energy consumption of existing and near-term vehicles involve modification of existing power plants (e.g., use of mixers to alter the fuel to air ratio) and the use of improved operating and maintenance procedures (e.g., developing maintenance procedures to keep engine performance close to its peak).

The potential for saving energy through improved maintenance procedures is obviously dependent upon the actions already taken by the Coast Guard.

Figure IV-2 depicts the relevance of existing and near-term vehicles in a Low Energy Setting. The rather limited range of options to lower the energy consumption of these vehicles can be noted in Figure IV-2.

(b) Technologies for New/Advanced Vehicles

The Coast Guard has a potential interest in a number of advanced vehicle concepts currently in the research and development stage. These advancements are expected to increase vehicle efficiency, durability, range, survivability and speed and should be in anticipation of an increase in the complexity and frequency of its future mission.

Figure IV-3 shows the relevance of advanced vehicles in the Low Energy Setting. With several exceptions, these vehicles are not LEV's per se. From a low energy perspective, they can be grouped into two categories; those which are inherently LEV's and those which can be equipped with fuel conserving technologies.

In the first category are vehicles such as (LTAV) Lighter-Than-Air Vehicle and Dynaship. (e.g., see refs. 3, 18, 48). The LTAV appears promising and is considered in this study. The Dynaship is still an unproven technology, and seems more suitable as a cargo vehicle rather than a performance vehicle. It is briefly described in Appendix H but is not considered in this report as a Coast Guard vehicle for the period 1980-2005.

FIGURE IV-1

LOW ENERGY SETTING AND ITS MAJOR COMPONENTS

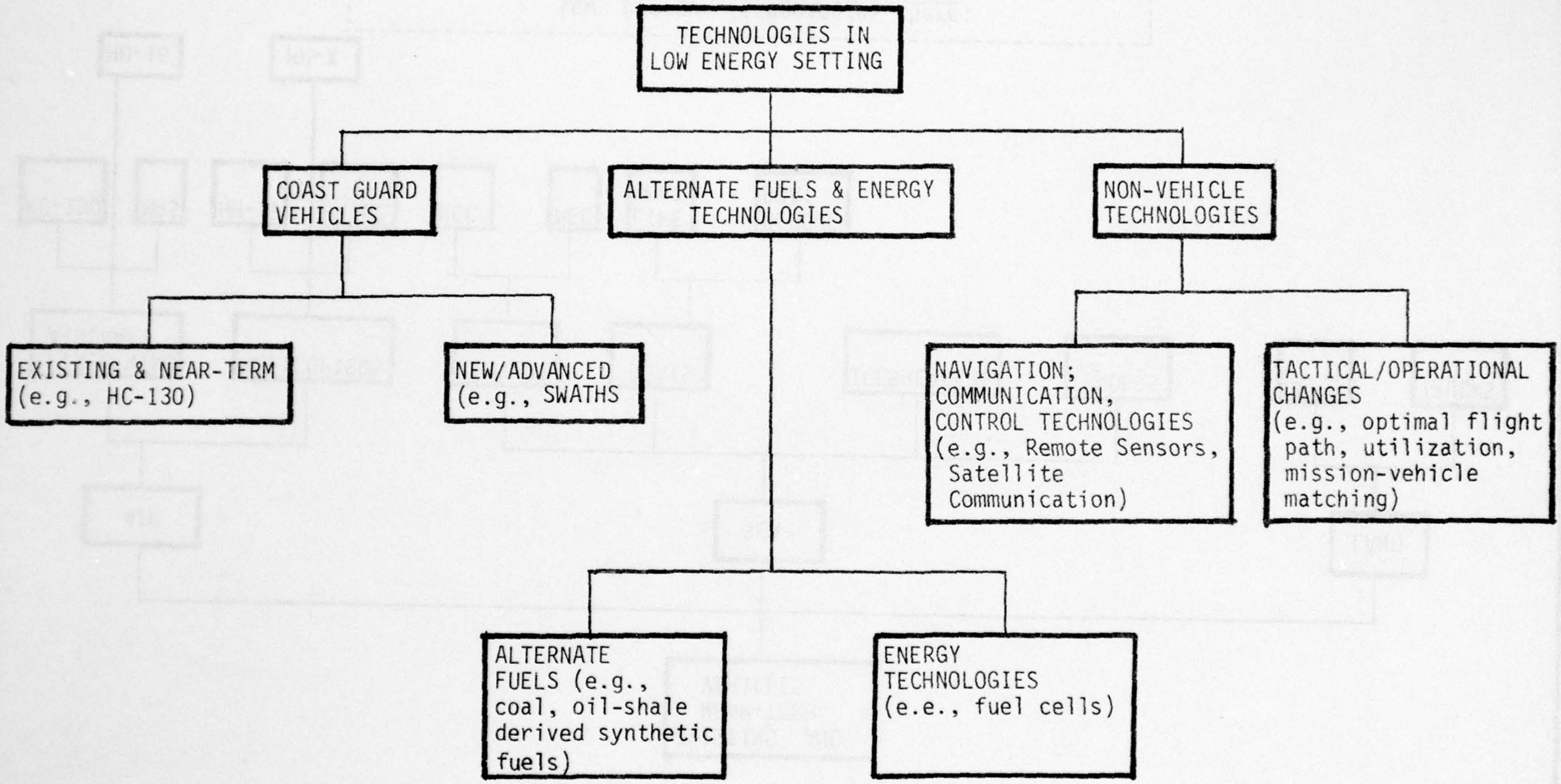
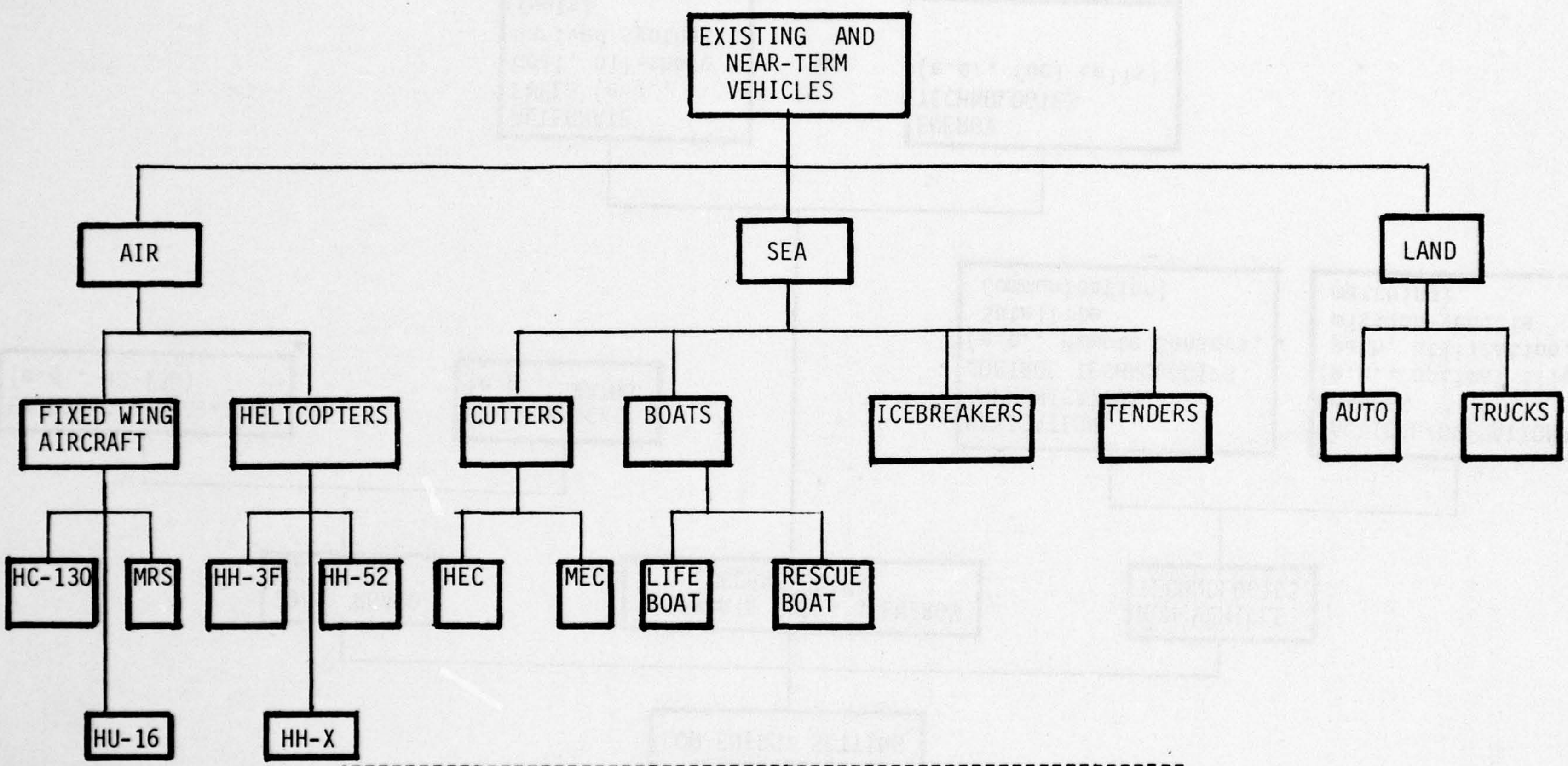


FIGURE IV-2

LOW ENERGY SETTING FOR EXISTING VEHICLES

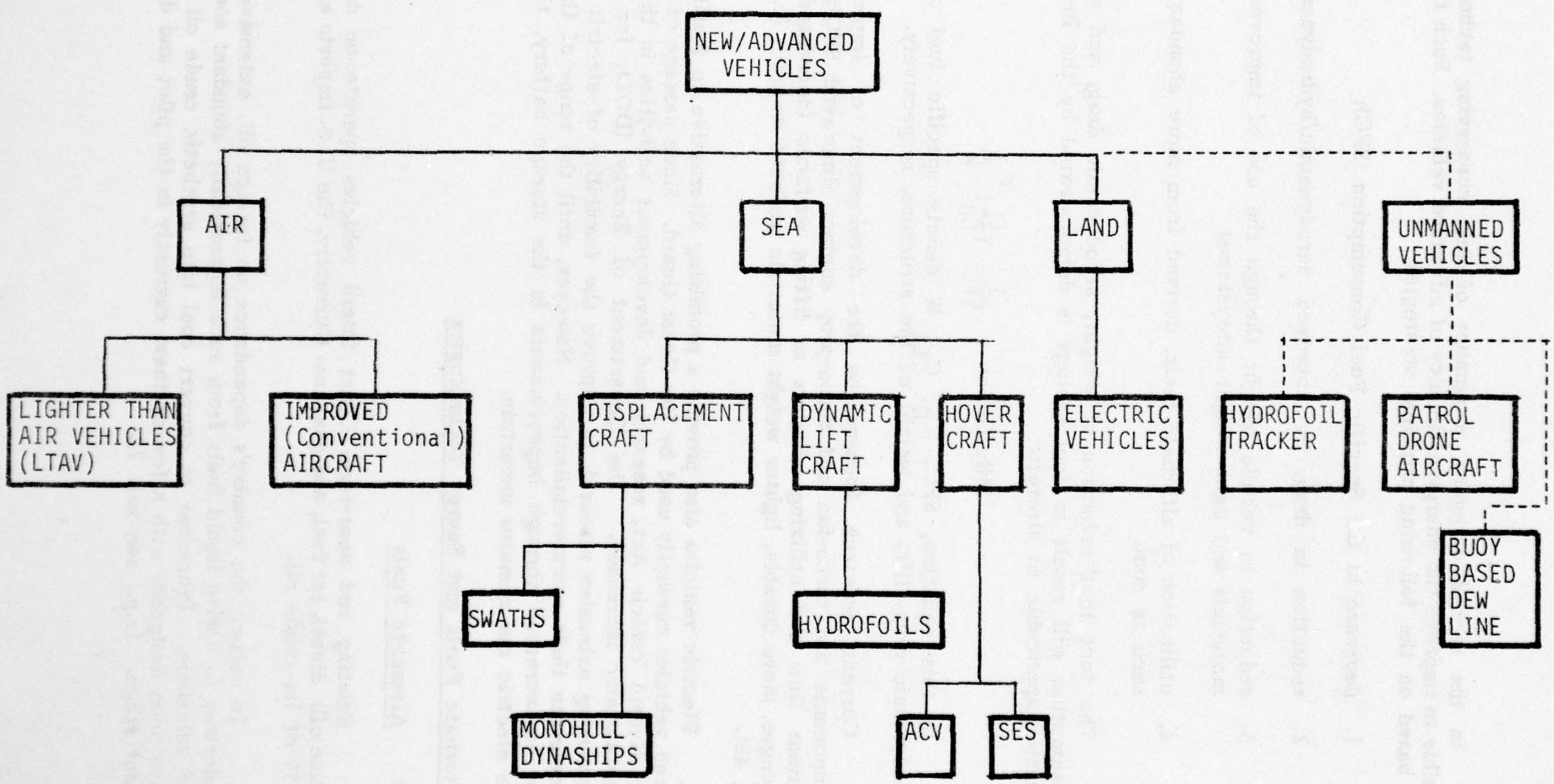


Low Energy Technologies here:

1. Improve the fuel efficiency of existing vehicles
2. Utilize improved operating/maintenance procedures

FIGURE IV-3

NEW/ADVANCED VEHICLES IN LOW ENERGY SETTING



Low Energy Technologies here are:

1. Vehicles which are inherently low energy (e.g., LTAV)
2. Technologies to reduce SFC
3. Technologies to reduce drag
4. Technologies resulting in improved structural design and the use of advanced materials
5. Technologies which shift to different fuels (e.g., electric cars)
6. Technologies resulting in weight reduction (e.g., use of superconducting machinery for propulsion transmission systems.)

In the second category, a number of fuel conserving technologies are possible to improve the energy efficiency of advanced vehicles. Such technologies are based on the following principal strategies:

1. decrease in the Specific Fuel Consumption (SFC);
2. reduction in drag, by improved aerodynamic/hydrodynamic design;
3. reduction in vehicle weight through the use of improved structural materials and light weight subsystems;
4. utilization of alternate fuels, derived from more abundant resources, such as coal.

The fact that reduction of weight, aerodynamic drag, and specific fuel consumption will result in fuel savings is demonstrated by the Breguet range equation applicable to aircraft:

$$\text{Mile/Gallon} = \frac{1}{SFC} \left(\frac{C_L}{C_D}\right)^{\frac{1}{2}} \frac{1}{W}$$

In this equation, SFC, C_D, C_L, W denote specific fuel consumption, aerodynamic drag, lift, and weight of the structure, respectively.

Current research focuses on the development of improved engine components and turbo-fan and turbo-prop engines (improved SFC); controlling laminar flow and utilizing winglets as lifting surfaces (decreased drag); and stronger, more durable, lighter weight materials (reduced weight); (e.g., see refs. 37, 45).

Electric vehicles also provide a promising alternative to fossil-fueled land based vehicles currently used by the Coast Guard. Since passage of the Electric and Hybrid Vehicle Act, research and development activities in this area have substantially increased. The Department of Energy (DOE), for example, is sponsoring extensive research to improve the feasibility of electric cars and to accelerate their commercialization. However, until the range of these vehicles can be increased through improvements in the storage battery, the future of the electric car remains uncertain.

2. Alternate Fuels and Energy Technologies

(a) Alternate Fuels

Existing and near-term Coast Guard vehicles operate on derivatives of crude oil: diesel, jet fuel, and gasoline. Currently, the U. S. imports approximately 45% of its crude oil.

To reduce the country's dependence on foreign oil, extensive research is underway to derive liquid fuels from such domestically abundant sources as coal and oil shale. Processes to convert coal into synthetic crude oil and gasoline have been designed, with a few of them currently in the pilot and demonstration plant stage. (e.g., see ref. 7).

Another potential fuel for Coast Guard vehicles, particularly aircraft, is liquid hydrogen. DOE and the Institute of Gas Technology (IGT) are investigating the technical and economic feasibility of this fuel. The National Aeronautics and Space Administration (NASA) has also sponsored studies to estimate the feasibility of hydrogen-powered aircraft. (e.g., see refs. 31, 32). According to current estimates, however, widespread use of hydrogen will not occur until after the year 2000. Furthermore, liquid hydrogen is difficult to store, reducing its military value. Consequently, hydrogen does not currently appear to be a feasible alternative for Coast Guard vehicles and has not been included in this study.

Research is also underway to derive liquid fuels from renewable resources, particularly biomass. This research, however, is focused more on producing fuels for automobiles (e.g., gasohol and methanol which can be used either directly or blended with gasoline) and is not suitable for aircraft and ships. We do not consider these fuels as promising options for the Coast Guard during the time frame of interest to this study, and have not included them.

(b) Alternate Energy Technologies

Solar energy and fuel cells provide significant alternate energy sources for Coast Guard operations. Solar photovoltaic cells and, to a lesser extent, wind-powered electric generators could be used to provide energy for onshore and offshore facilities. (e.g., see ref. 14). However, fuel cells do require fuel inputs (e.g., methane distillate, methanol, naphtha) which must either be stored or continuously produced on-site. Photovoltaic and fuel cells are included in this study.

Photovoltaic cells convert solar energy directly into electricity. Currently available photovoltaic cells are expensive (approximately \$5000/KW) and their conversion efficiency is low (approximately 5% to 7%). Extensive research is underway to overcome both of these disadvantages. Photovoltaics could find significant application in remotely located Coast Guard platforms, particularly navigation equipment and buoys. The Coast Guard is currently experimenting with the use of photovoltaics for buoys on the Atlantic Coast.

Fuel cells convert the chemical energy stored in a fuel directly into electric energy. No combustion takes place during this conversion. A fuel cell consists of a catalyst to promote the chemical reaction, two electrodes, and an electrolyte which conducts electricity. Hydrogen contained in the fuel and oxygen from the air combine to produce electricity and water. Fuel cells are a promising power source on Coast Guard ships because they are safe and "clean". (e.g., see Ref. 9).

The utilization of nuclear power to propel Coast Guard vehicles is possible, although it applies only to the cutters; particularly ice breakers. Because of its very limited application to Coast Guard use and, more importantly, because of current concern over the use of nuclear power in the proximity of human settlements, nuclear powered vehicles have not been included in the study.

The application of alternate fuels and technologies in a low-energy setting is summarized in Figure IV-4. The summary also indicates the extent to which the alternate fuels and advanced energy technologies will be compatible with existing and near-term Coast Guard vehicles.

3. Non-vehicle Technologies

Low energy technologies here are of two major types:

(a) Technologies which reduce or eliminate, through functional substitution, the need for a particular task. For example, advanced navigation and communication techniques can eliminate, or reduce vehicular use. Some activities of the SAR and ELT missions can be substantially reduced through reliance on satellite communications and navigation systems and computerized monitoring.

(b) Tactical and operational changes which can lower energy consumption. For example, flight parameters can be planned to optimize fuel consumption or the optimum speed selected to operate the vehicle at its peak fuel efficiency.

Because of their familiarity, it is tempting to focus on technologies in category (b) above. However, these technologies are of limited potential. Technologies in category (a) above require a more radical shift but are more likely to produce significant long-term gains, albeit at an increased cost. Coast Guard missions, particularly SAR, ELT, MEP, AN, and MSA, could significantly benefit from the development and utilization of such technologies. For example, advanced navigation, communication and control systems such as the GPS (Global Positioning System) and SEASAT could produce substantial energy savings.

The development of remote sensors has advanced very rapidly during the last decade. These sensors (e.g., infrared camera, multispectral scanners) can be useful in locating ships, detection of pollution, detection and port protection. Use of remote sensors could reduce search time, resulting in energy savings.

The application of non-vehicle technologies in a low energy setting is summarized in Figure IV-5. It can be seen that the span of technologies is indeed large. In this study, we have considered only those technologies which appear promising for Coast Guard use.

C. Technology Forecasts

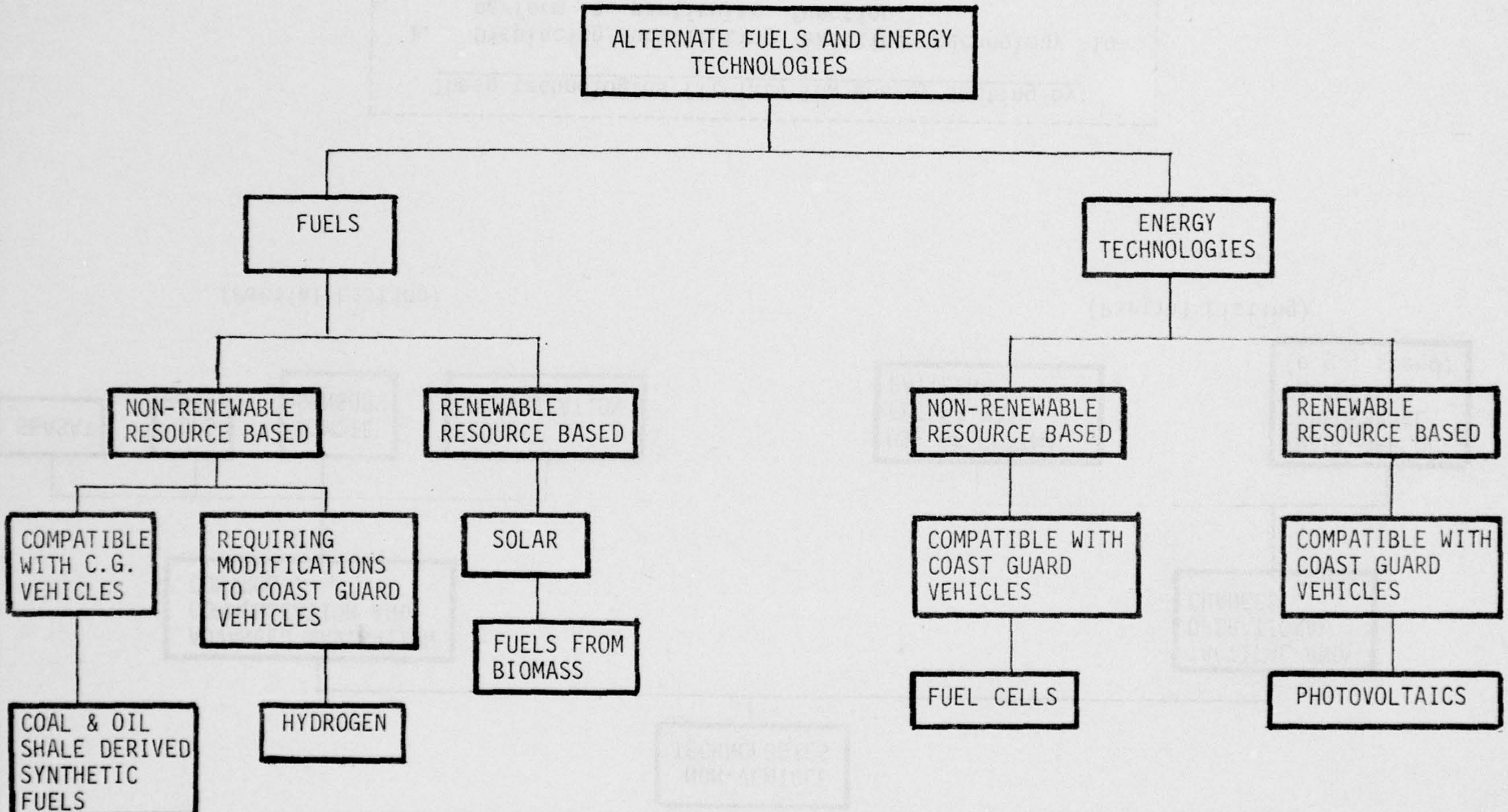
For each component of the Low Energy Setting (LES), there are several technologies which can affect Coast Guard energy requirements. In many cases, such technologies are already in the research and development stage. To compare the energy impacts of different Coast Guard vehicles, we have also developed estimates of the likely availability of advanced vehicles such as hydrofoils and SWATHS (Small Waterplane Area Twin Hull Ship).

1. Method of Approach

Technology forecasts are derived by analytical and judgmental techniques. (e.g., see refs. 12, 23, 28, 29, 43). The overall approach is shown in Figure IV-6(a) to IV-6(d) for the major components of LES. The first step in each area is to identify the technologies, or means, to lower the energy requirements; for example, in the case of existing vehicles, a relevant technology involves improvement in engine components, such as a mixer, to reduce SFC (Specific

FIGURE IV-4

ALTERNATE FUELS AND ENERGY TECHNOLOGIES IN LOW ENERGY SETTING

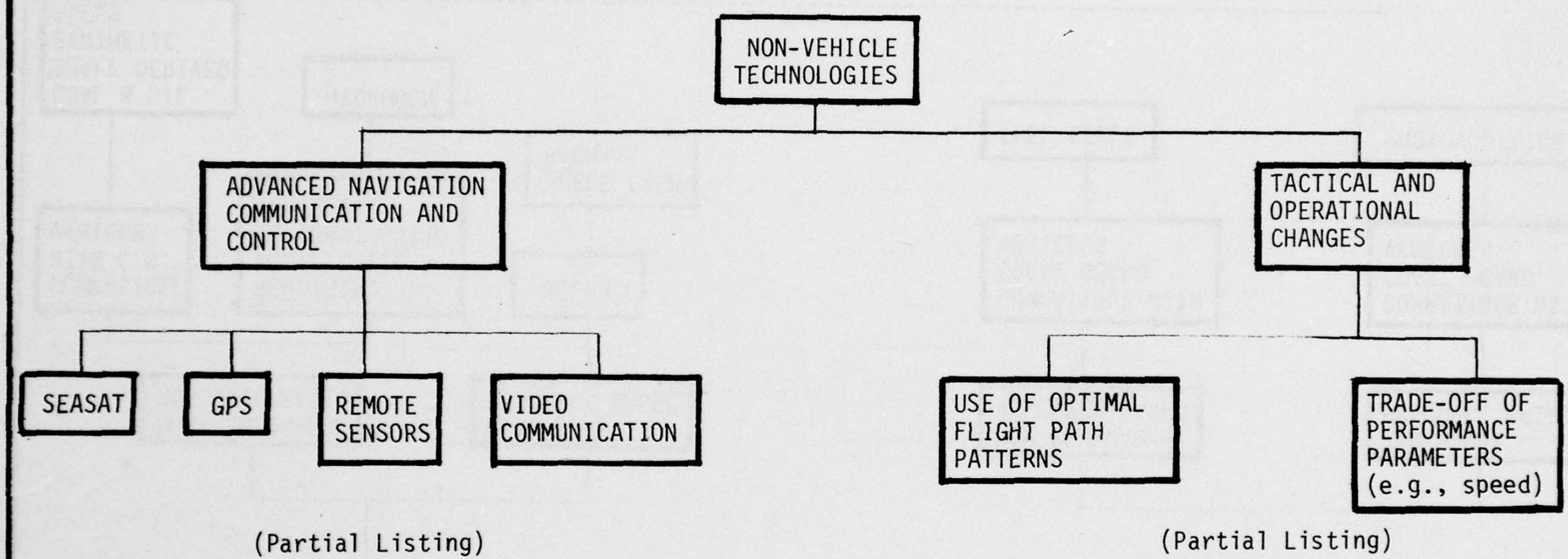


These technologies fit into low energy setting by:

1. Substituting for fuels currently used in Coast Guard vehicles
2. Substituting power sources currently used in Coast Guard platforms

FIGURE IV-5

NON-VEHICLE TECHNOLOGIES IN A LOW ENERGY SETTING



These technologies fit into low energy setting by:

1. Displacing/substituting existing technology to perform a particular function
2. Changing tactics for performing the mission

FIGURE IV-6 (a)

COMPONENTS OF TECHNOLOGY FORECAST FOR EXISTING AND NEAR-TERM VEHICLES

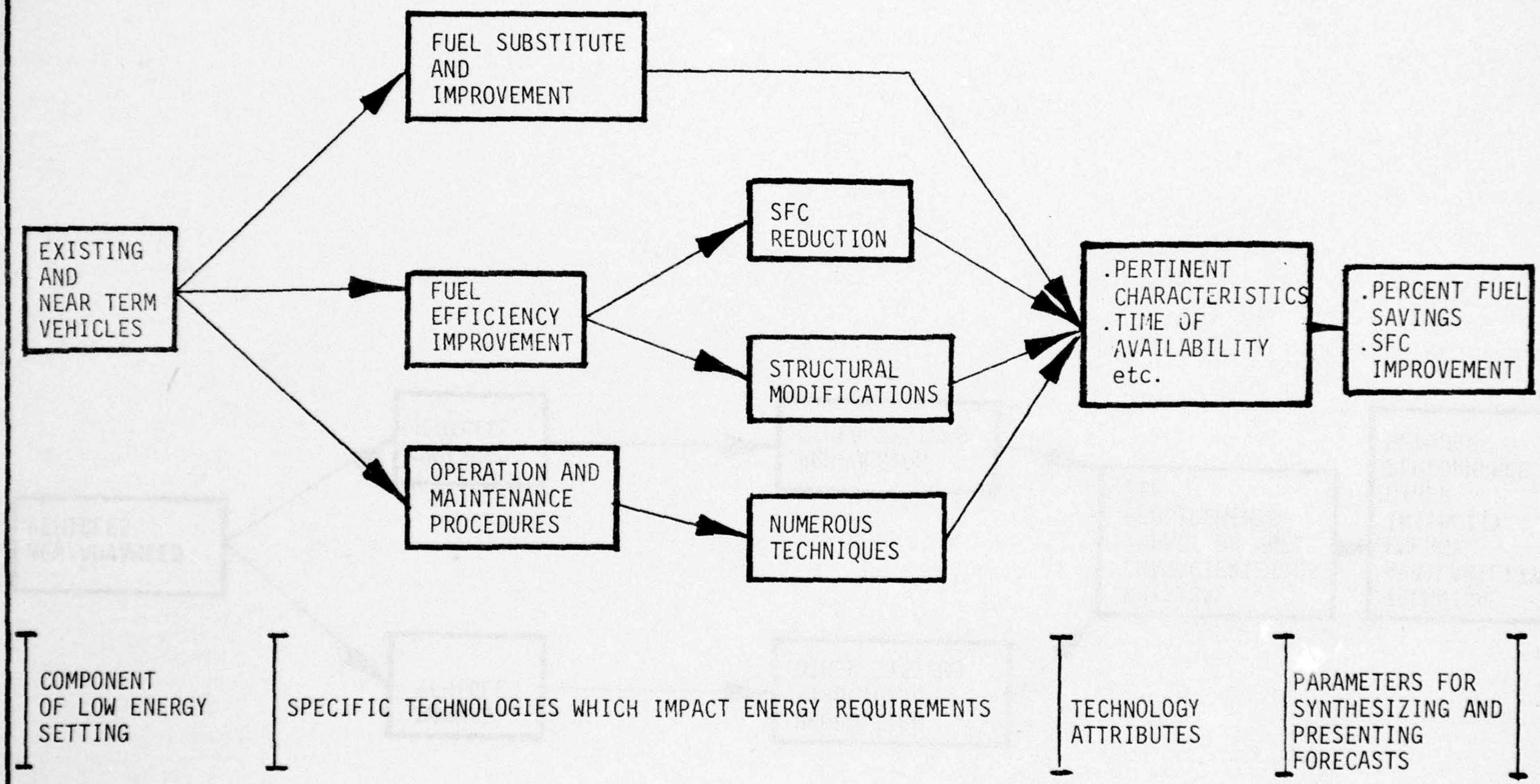


FIGURE IV-6 (b)

COMPONENTS OF TECHNOLOGY FORECAST FOR NEW/ADVANCED VEHICLES

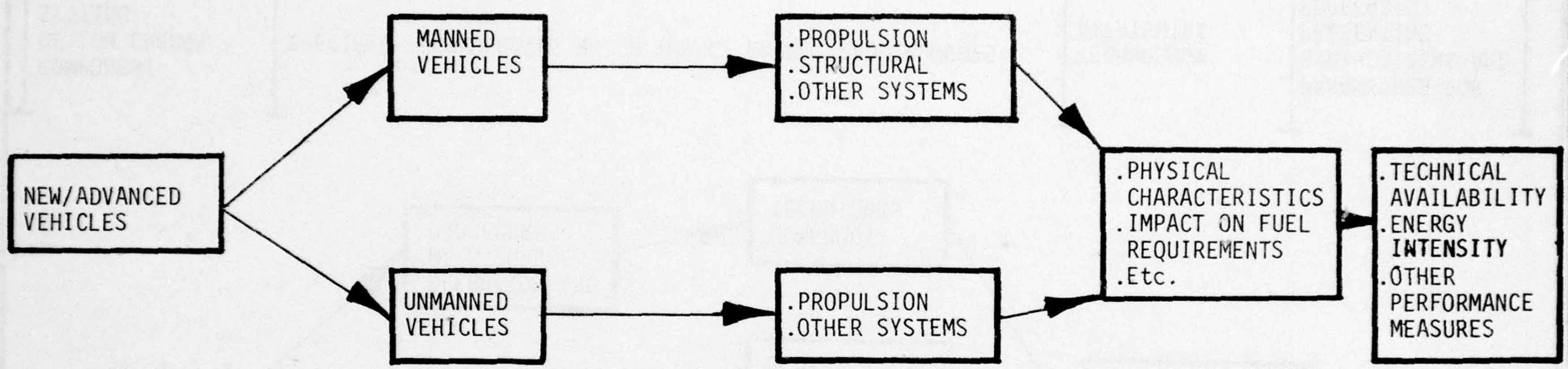


FIGURE IV-6 (c)

COMPONENTS OF TECHNOLOGY FORECAST FOR ALTERNATE FUELS AND ENERGY TECHNOLOGIES

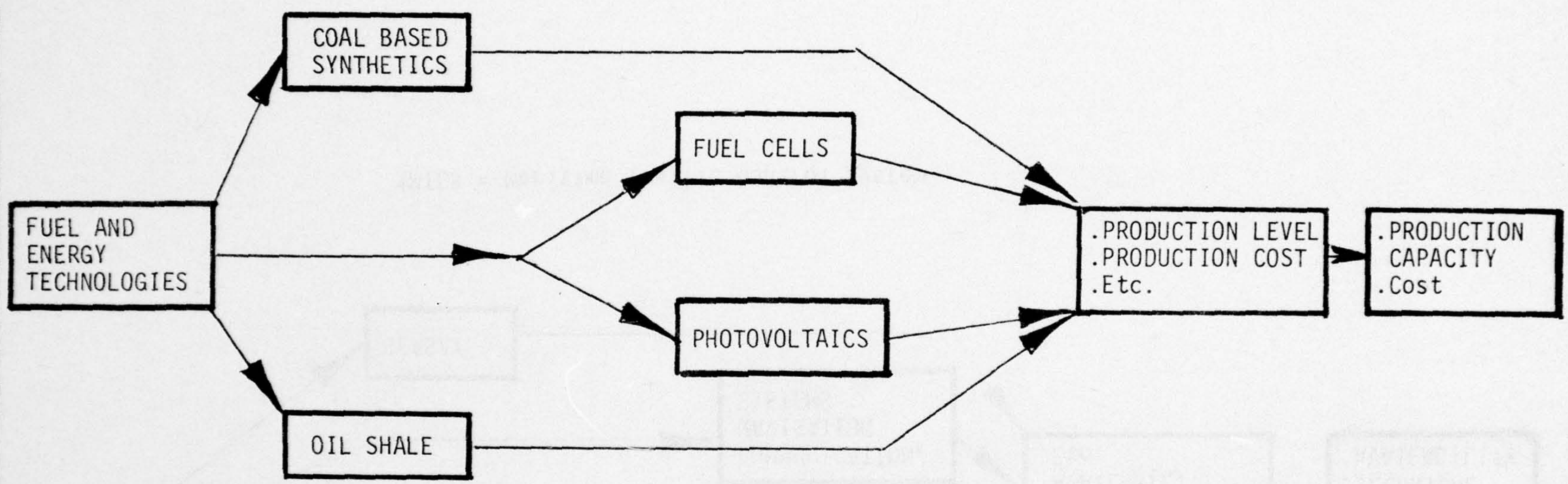
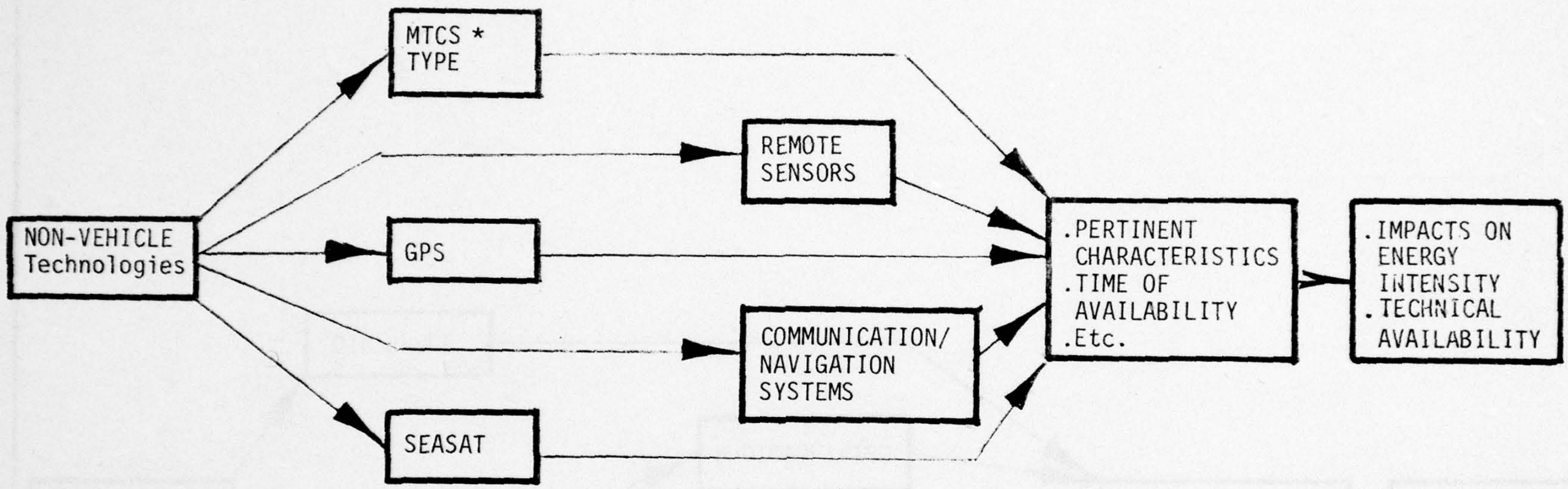


FIGURE IV-6 (d)

COMPONENTS OF TECHNOLOGY FORECAST FOR NON-VEHICLE TECHNOLOGIES



*MTCS = Maritime Traffic Control System

Fuel Consumption). The second step is to identify those parameters of each relevant technology which characterize it for purposes of the technology forecasts, and also those parameters necessary to present the technology forecasts. For example, parameters chosen for engine component improvement technology include the percent fuel saved (reduction in SFC) and the characteristics of particular components such as mixer and rotor blades. Finally, forecasts are developed by using analytical and judgemental techniques; for example, substitution models (Ref. 10, 24, 27, 28) are used to develop estimates for some of the fuel and energy technologies, while estimates of the potential energy savings for the existing aircraft through better maintenance and operation are derived by reviewing and evaluating the work being done by NASA, FAA, and aircraft industries. (e.g., see refs. 6, 15, 37, 45).

Forecasts developed through this approach are then summarized. The discussion focuses on the principal characteristics of the forecasts.

2. Existing Vehicles

Energy consumption of existing vehicles can be reduced by using the following technologies:

(a) installing improved engines whenever an opportunity for engine replacement occurs, or when ordering additional units of the existing vehicle;

(b) installing improved engine components (e.g., mixers) when such components become available;

(c) improving maintenance and operation of the vehicle.

Improvements for specific vehicle types are as follows:

Aircraft

* For aircraft, technologies capable of reducing SFC can produce energy savings of 4% to 6% per aircraft, in terms of the current fuel consumption. These technologies are primarily applicable when the engine or its major components are being replaced (Figure IV-7). These forecasts are developed by comparing situations analogous in the civilian aircraft industry. (e.g., see refs. 15, 37).

Helicopters

* The results for helicopters are similar to those for other aircraft, through reduced SFC and improved maintenance and operation procedures. (Figures IV-9 and IV-10).

Cutters, Boats, and Icebreakers

* Cutters and boats rely primarily on diesel engines. Again, SFC improvements are possible through better designed engine components. However, improvement in specific fuel consumption for diesel engines is expected to be quite modest, amounting to about 1.5%. (Figure IV-11).

* Some large cutters and icebreakers use gas turbines to boost their performance. (Ref. 20). Improved technology can result in substantial improvement in SFC, amounting to 15% to 25%. (Figure IV-12).

EXISTING VEHICLES

AIRCRAFT

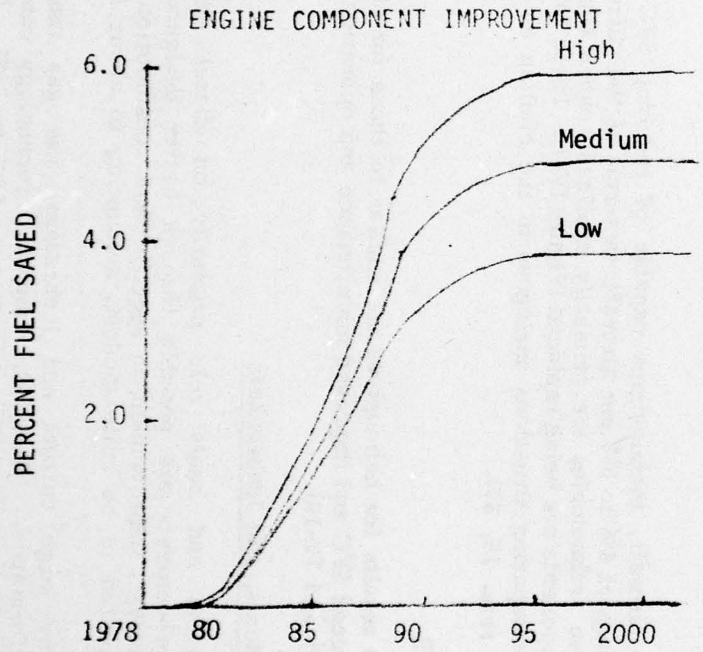


Figure IV-7

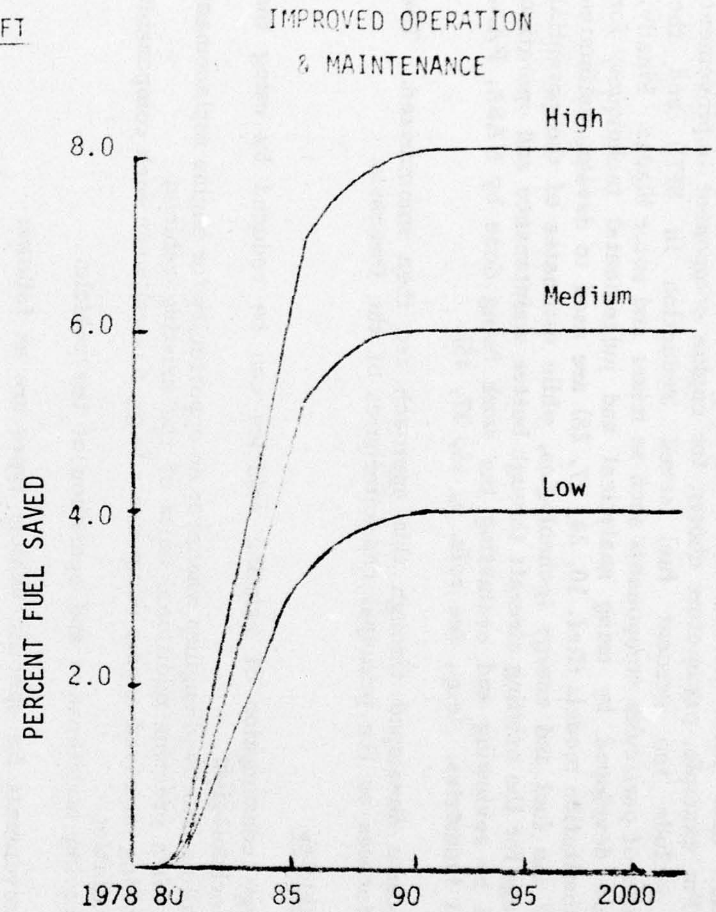


Figure IV-8

AD-A079 320 NERO AND ASSOCIATES INC PORTLAND OR F/G 13/10
TECHNOLOGY ASSESSMENT OF LOW ENERGY VEHICLES.(U)
SEP 79 H A LINSTONE, R DAWSON, Y GUR DOT-CG-835030
UNCLASSIFIED TF019 USCG-D-64-79 NL

2 OF 4
AD
A079320

EXISTING VEHICLES

HELICOPTERS

ENGINE COMPONENT IMPROVEMENT

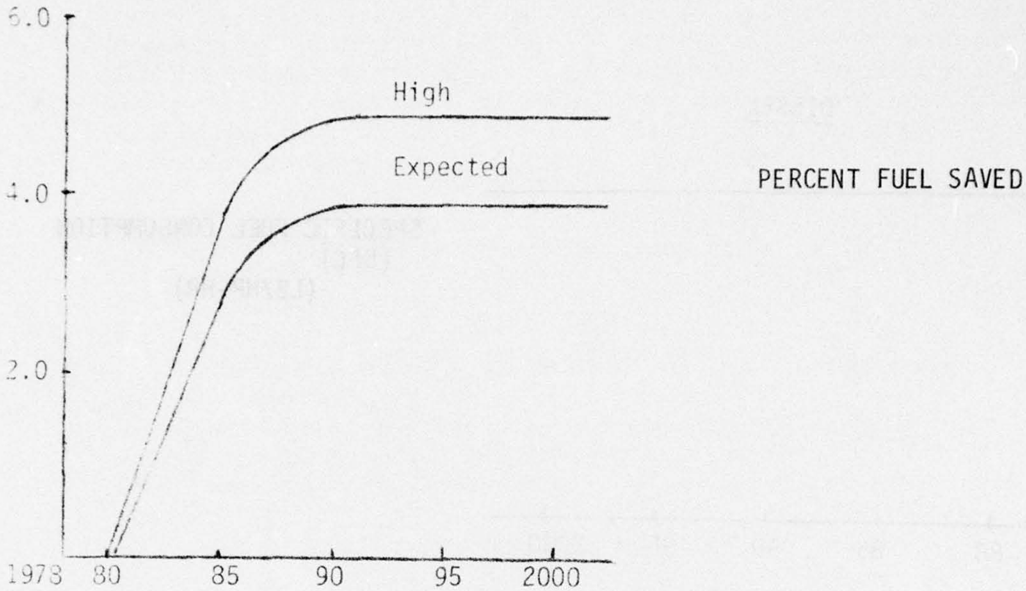


Figure IV-9

IMPROVED OPERATION MAINTENANCE

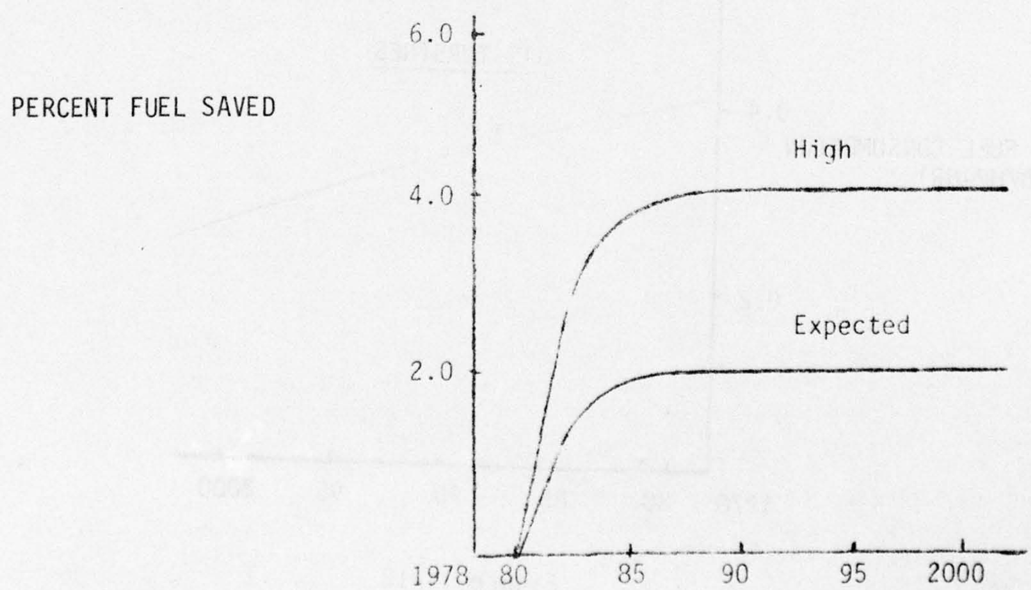


Figure IV-10

EXISTING VEHICLES-
(CUTTERS / BOATS / ICEBREAKERS)

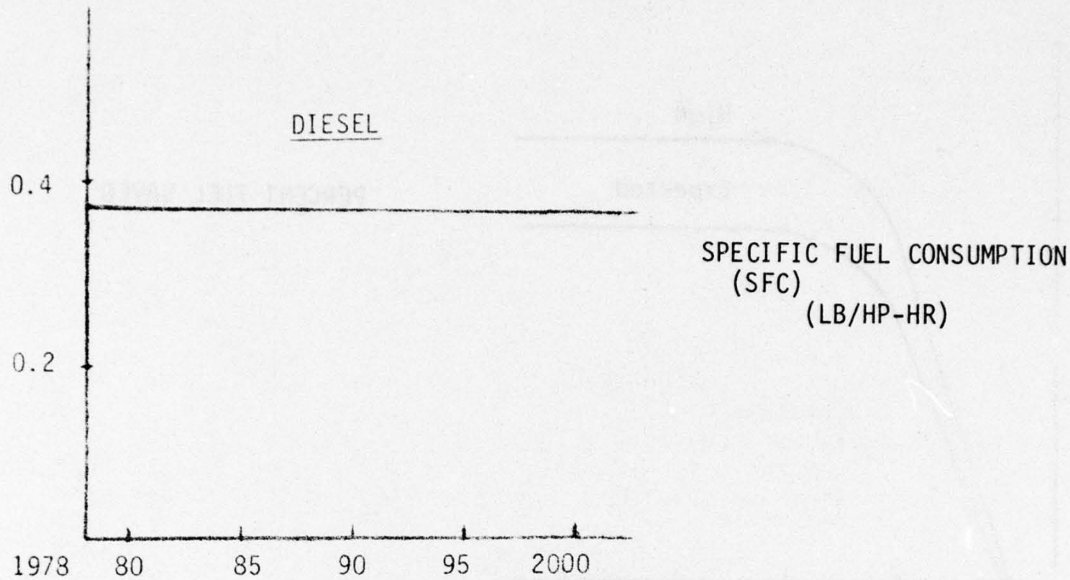


Figure IV-11

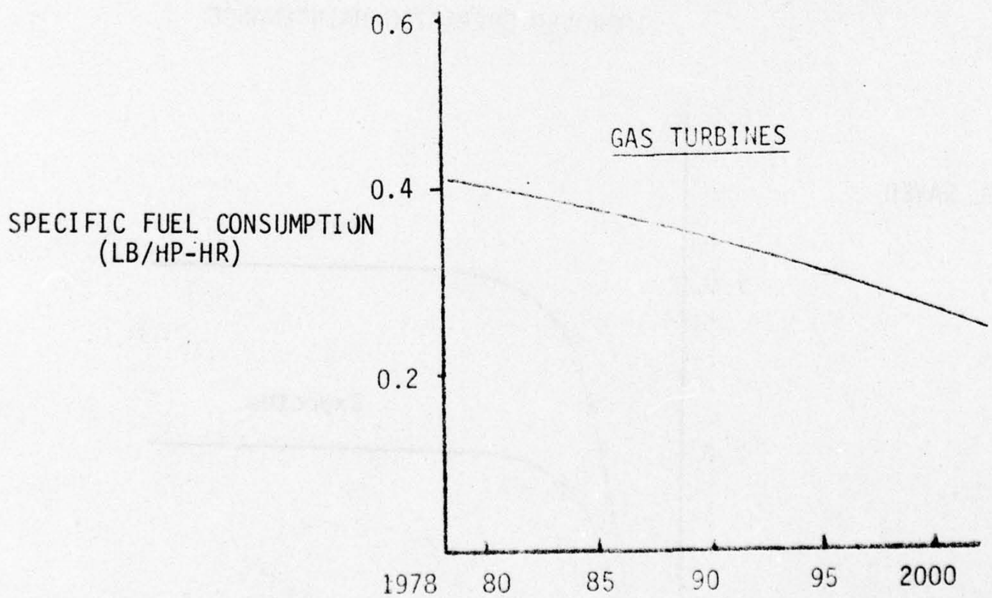


Figure IV-12

* Improved maintenance and operation can also reduce fuel use of these vehicles. The potential savings may amount to 4% to 10%.

Automobiles

* Substantial improvements in fuel efficiency are expected for the internal combustion engines, primarily in response to the standards established in the Energy Conservation and Policy Act. (e.g., see ref. 46). These improvements can be achieved through the use of lighter materials (aluminum, plastics, and high strength low alloy steels) to reduce weight and changes in power plant design, e.g., use of stratified charge engines (Figure IV-13).

* It has also been shown that improved maintenance and operation of automobiles can produce significant fuel savings. A well maintained automobile can yield fuel efficiency improvement of up to 3 to 5 miles per gallon.

3. New/Advanced Vehicles

(a) Technology Availability

Table IV-1 contains estimates of the most likely period of availability of advanced vehicles for Coast Guard use. In fact, it contains estimates of almost all technologies constituting the LES.

A number of vehicles under development are of potential interest to the Coast Guard. These vehicles include Air Cushion Vehicles (ACV), Surface Effect Ships (SES), Hydrofoils, Small Waterplane Area Twin Hull (SWATH) Ship, Lighter-Than-Air Vehicles (LTAV), Vertical Take off and Lift (VTOL) aircraft, Wing-in-the-Ground Effect Ship (WIGES), Electric vehicles (cars), and three unmanned vehicles: Patrol Drone Aircraft, Buoy Based Dew Line, and Hydrofoil Tracker. (e.g., see refs. 5, 11, 12, 16, 17, 21, 22, 33, 34, 49).

The conceptual design of most of these vehicles is relatively well established. However, in most cases, only a prototype vehicle has been constructed. It is possible, at least theoretically, to scale the prototype to a fleet size vehicle which may ultimately be part of the Coast Guard fleet. However, such scaling is an involved, complex process and has not been attempted for this analysis. Nevertheless, some major trends are discernible.

The estimation of technological availability of these vehicles is far from straightforward. The Coast Guard, to a large extent, undertakes only limited research on advanced vehicles and does not sponsor design and development of such vehicles. Thus, in addition to the usual factors related to technoeconomics, substitution and performance matching, factors germane to transfering the technology to meet Coast Guard needs must be considered. Organizational constraints appear as important and influential factors in determining the technological availability of the advanced vehicles. (See Chapter VI).

Our approach has been designed to include the above considerations. Comprehensive estimates of vehicle availability were developed by: (a) a review of the literature; (b) contact and discussion with individuals involved in the research and development of these vehicles, e.g., Naval Research and Development Center; (c) assessment of the various interacting factors, including

AUTOMOBILES

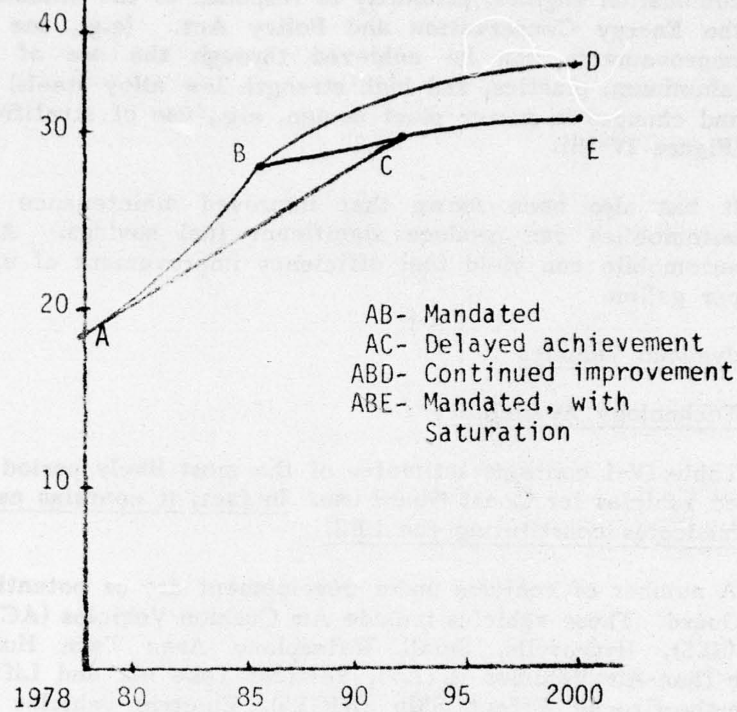


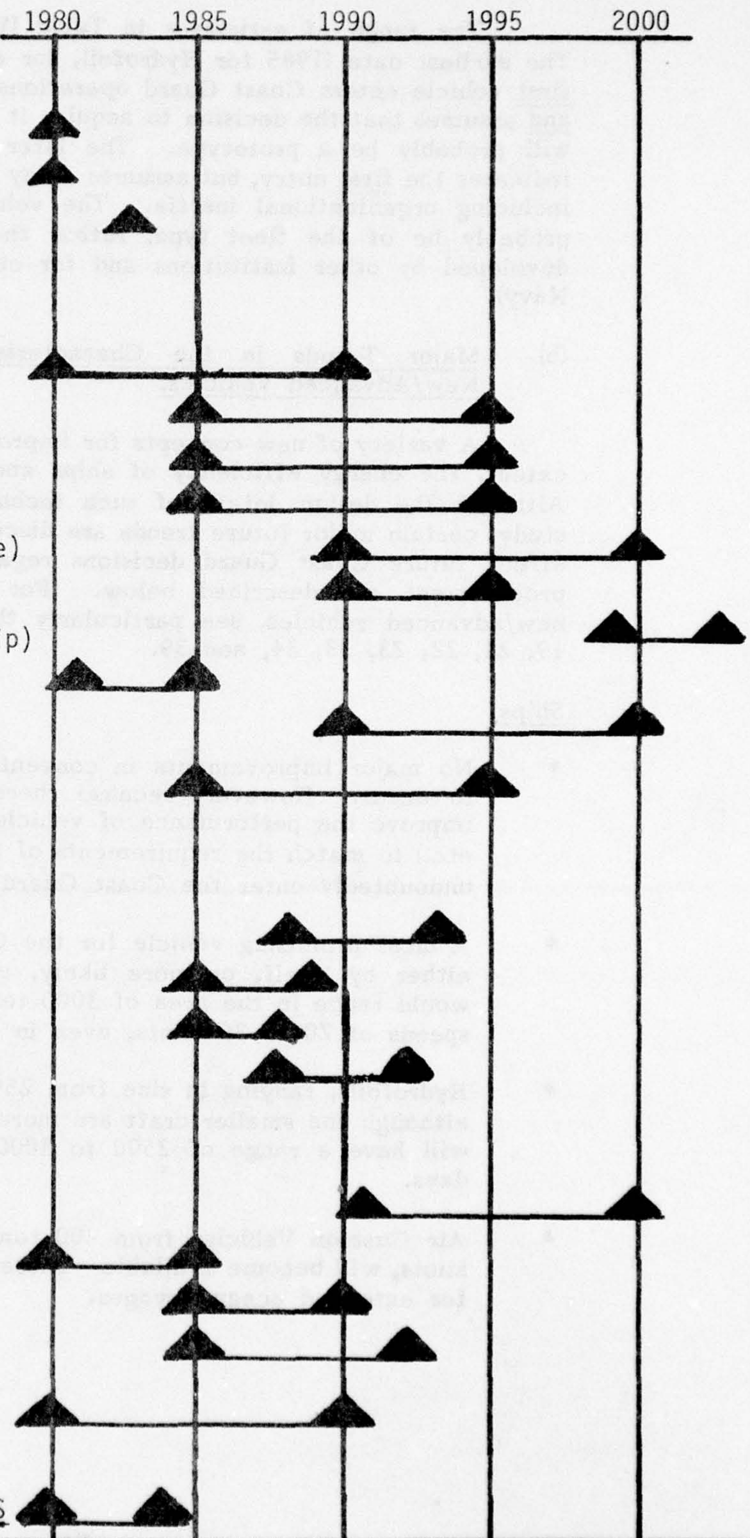
Figure IV-13

FUEL CONSUMPTION (MILES PER GALLON)

TABLE IV-1

TECHNOLOGIES IN A LOW ENERGY SETTING

(Time of Availability for Coast Guard Use)



NEAR TERM ADDITIONS

- MRS Aircraft
- WMEC-270' Cutter
- SRR Helicopter

NEW/ADVANCED VEHICLES

- Air Cushion Vehicles
- Surface Effect Ships
- Hydrofoils
- SWATH Ship
- Airship (Lighter-Than-Air Vehicle)
- STOL Type Aircraft
- WIGES (Wing-in-Ground-Effect Ship)
- Electric Cars
- Unmanned Vehicles (patrol drone aircraft, buoy based dewline, hydrofoil tracker)

FUELS AND ENERGY TECHNOLOGIES

- Synthetic Fuels - coal derived
- Synthetic Fuels - oil shale
- Fuel Cells
- Solar Photovoltaics

NON-VEHICLE TECHNOLOGIES

- MTCS Type
- Remote Sensors (IR, SAR, Etc.)
- GPS
- SEASAT
- Communication/Navigation Systems (Loran, Etc.)

OPERATIONAL/ORGANIZATIONAL APPROACHES

the requirement of matching vehicle characteristics with those of the Coast Guard missions; (d) revision of the estimates; and (e) derivation of end points of the time period over which the technology could become available. Specification of a time span rather than a single point is more realistic to account for uncertainties in availability.

The range of estimates in Table IV-1 should be interpreted as follows: The earliest date (1985 for Hydrofoil, for example) indicates the time when the first vehicle enters Coast Guard operations under the most favorable conditions and assumes that the decision to acquire it is made relatively soon. This vehicle will probably be a prototype. The later date for the Hydrofoil (1995) again indicates the first entry, but assumes delay caused by unfavorable circumstances, including organizational inertia. The vehicle available in 1995, however, will probably be of the fleet type, rather than a prototype, having already been developed by other institutions and for other purposes (for example, the U. S. Navy).

(b) Major Trends in the Characteristics and Energy Requirements of New/Advanced Vehicles.

A variety of new concepts for improving the performance and, to a lesser extent, the energy efficiency of ships and aircraft is currently being pursued. Although the design details of such technologies are beyond the scope of this study, certain major future trends are discernible. Trends likely to significantly affect future Coast Guard decisions regarding mission operations and vehicle procurement are described below. For description and discussion of many new/advanced vehicles, see particularly the references 2, 3, 5, 12, 13, 16, 17, 19, 21, 22, 23, 33, 34, and 39.

Ships

* No major improvements in conventional displacement vehicles are likely to occur. However, because there will be a significant motivation to improve the performance of vehicles (increased speed, longer endurance, etc.) to match the requirements of future missions, advanced vehicles will undoubtedly enter the Coast Guard fleet.

* A most promising vehicle for the Coast Guard will be the SWATH Ship, either by itself, or more likely, equipped with helicopters. Such ships would range in the area of 3000 tons or more in displacement and attain speeds of 20 to 30 knots, even in rough waters.

* Hydrofoils, ranging in size from 250 to 2000 tons may become available, although the smaller craft are more likely within this study. These craft will have a range of 2500 to 3000 miles and an endurance of about 30 days.

* Air Cushion Vehicles from 200 tons and ranging in speed from 50 to 80 knots, will become available. These vehicles, however, will not be suitable for extended ocean voyages.

* Surface Effect Ships will be available. Their size would vary from 200 to 3000 tons, although, like hydrofoils, the smaller vehicles are more likely to be available within the time frame of this study.

* Several hybrid vehicles seem promising; among them, the Cutter-Barge and Icebreaker-ACV combinations seem particularly attractive. (Ref. 40, 50). The former permits on-board weight reductions by the transfer of certain crew and storage facilities into the barge. The concept should also allow the size reduction of future cutters. Regarding the latter concept, the Coast Guard is currently experimenting with this concept in the removal of ice on the Great Lakes.

* Use of high strength, low-alloy steels, aluminum, and composite materials for hull structures is likely to result in substantial weight reduction accompanied by energy savings.

<u>Aircraft</u>

* The need for fuel saving will undoubtedly affect the design of future aircraft. The following means are likely to play a prominent role in reducing energy requirements: improved aerodynamic design to reduce drag; improved thermodynamic efficiency for reducing SFC; and reduced weight through improved aircraft design and the use of lighter materials. In addition, the use of active controls on future aircraft is likely to grow.

* SFC improvement through the use of regenerative engines is likely to reduce fuel use by about 5 percent, depending upon lead time (10 to 15 years) to develop and implement the technology (Figure IV-14).

* Aerodynamic drag will be reduced through the use of supercritical technology (i.e., design with higher aspect ratio and longer wing sweeps), active controls, and laminar flow control. The resulting savings could amount to about 15%, 5%, and 20% to 40%, respectively, for these three options (Figures IV-15, IV-16, and IV-17).

* Weight of future aircraft will be substantially reduced by using improved materials, such as advanced composites, and improved aircraft design. The resulting energy savings could amount to 10% to 15% (Figure IV-18).

<u>Helicopters</u>

* Some of the technological development described above for aircraft should also influence helicopter technology. However, we do not foresee any substantial improvement in helicopter technology during the time period of this study.

<u>Airships, Lighter-Than-Air Vehicle</u>

* Although not exactly an advanced vehicle, airships are probably the most useful of the new vehicles. Given certain design parameters, they can truly be termed low energy vehicles. (e.g., see refs. 3, 18). These vehicles are likely to range from 5 to 300 tons, with speeds of 50 to 100 knots, a range of 1000 to 3000 miles, and an endurance of up to three days. Airships are the only vehicles which occupy the promising region on the Gabrielli-Von Karman line (i.e., in the speed range of 50-80 knots). This aspect is more fully examined in Chapter V. (cf Figure V2); also see refs. 13, 25, 26.

AIRCRAFT

NEW/ADVANCED VEHICLES

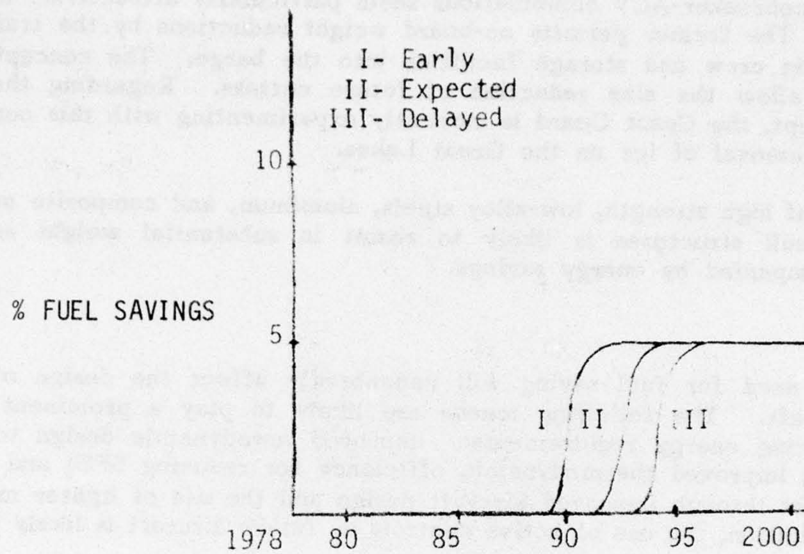


FIGURE IV-14 SFC IMPROVEMENT THROUGH REGENERATIVE ENGINES

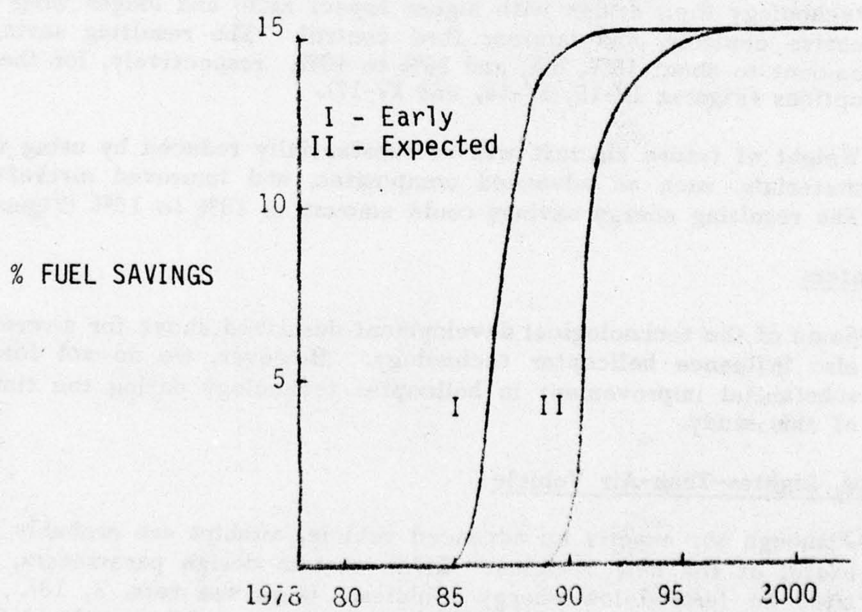


FIGURE IV-15 DRAG REDUCTION THROUGH SUPERCRITICAL TECHNOLOGY

AIRCRAFT
NEW/ADVANCED VEHICLES

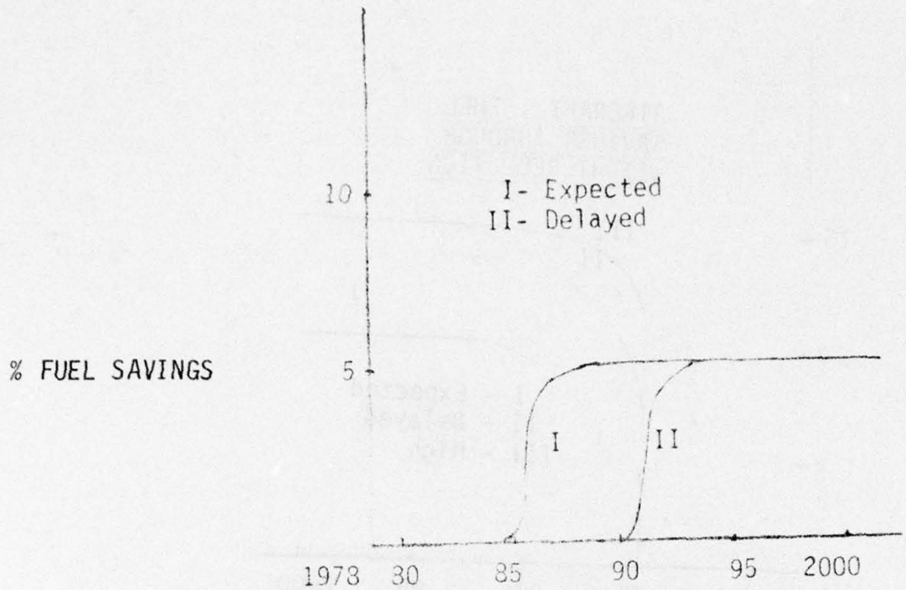


Figure IV-16 DRAG REDUCTION THROUGH ACTIVE CONTROLS

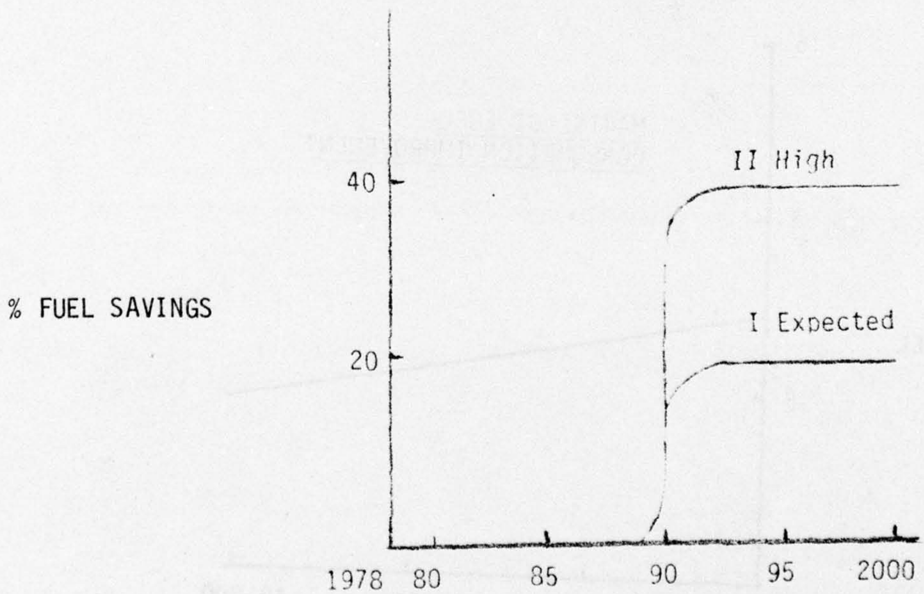


Figure IV-17 DRAG REDUCTION THROUGH LAMINAR FLOW CONTROL

NEW/ADVANCED VEHICLES

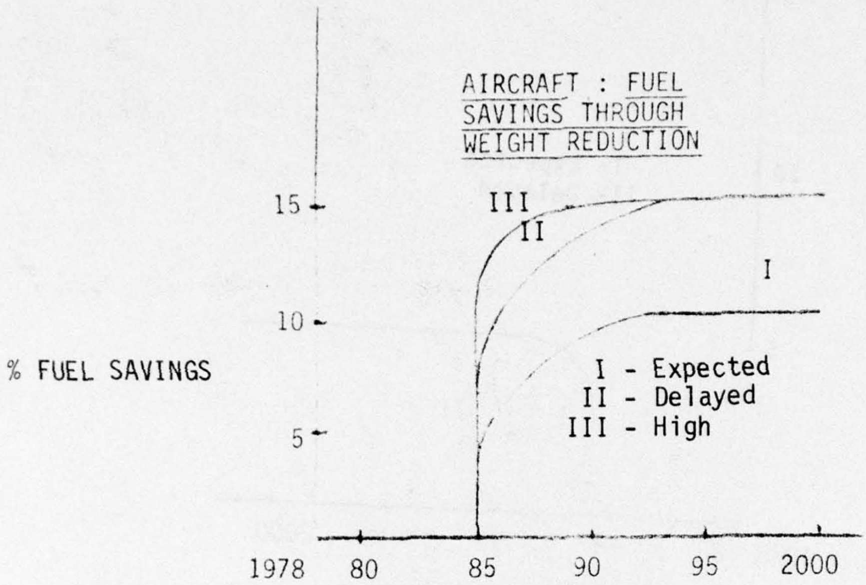


Figure IV-18

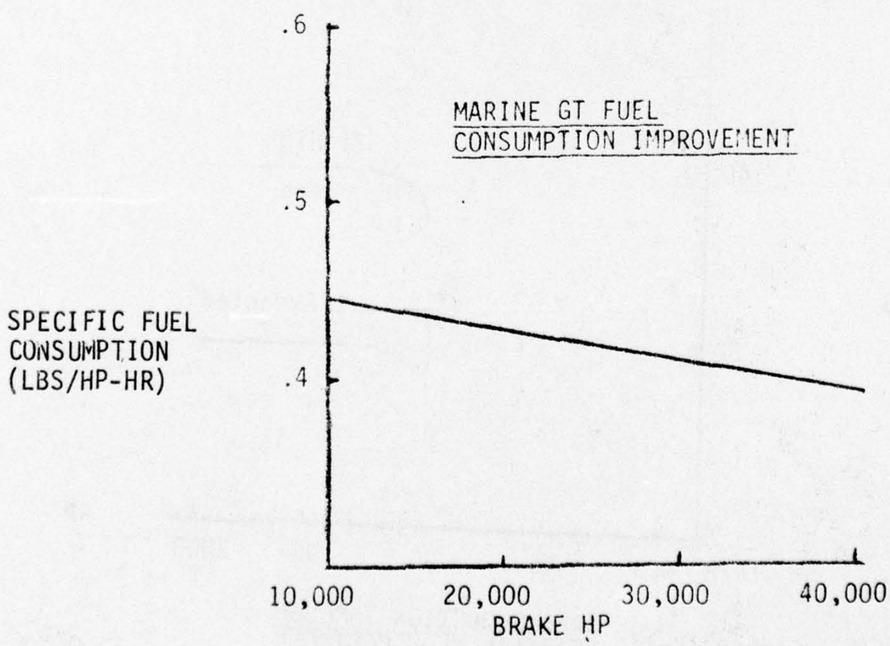


Figure IV-19

Automobiles

* The only replacement for the conventional automobile is an electric car, as far as automobile technology is concerned. Since the passage of the Electric and Hybrid Vehicles Act, much research is underway to increase the durability and range of electric cars through improvements in storage batteries. The estimates of market penetration of electric cars vary, ranging from about 500,000 to 2 million in the year 2000 (Figure IV-21).

* The future of electric vehicles will probably be determined by organizational and institutional constraints rather than technoeconomics. Among these, the utilization of existing infrastructures (gasoline distribution systems, for example) and the cooperation of the auto and oil industries will be the most important.

Propulsive Systems

* Improvements in diesel engines are likely to be very modest. However, the development of rotary diesel engines could be of interest to future Coast Guard vehicles.

* Gas turbines will be the primary "work horse" of future advanced vehicles. The ability of gas turbines to deliver large amounts of power with smaller size and weight makes them the most attractive power plant for future vehicles. Ceramic gas turbines will probably appear before 2005, but are not likely to be attractive for Coast Guard use. (e.g., see refs. 23, 43).

* COGAS (Combined Cycle Plant using Gas Turbines) is also an attractive possibility for ship propulsion because of its superior thermodynamic efficiency. The use of COGAS plant in Coast Guard vehicles, however, is likely to be small because of their design and operational complexity. (Ref. 1).

* Perhaps the most dramatic improvement in the propulsion systems will be in the transmission system (i.e., the system linking the power plant to the propeller). Significant weight reductions are likely, as an electrical transmission system will be substituted for the conventional gear-box systems. The research on superconducting machinery will be especially rewarding in this regard. Weight reductions of from 300% to 500% are likely, which will directly translate into fuel savings. (e.g., see refs. 23, 36).

Operation and Maintenance

* Significant fuel savings for advanced vehicles are likely, given two important operational and maintenance considerations. First, crew size will be lowered, because of automation, resulting in significant fuel savings. Second, the use of modular designs and automated fault detection systems will increase the utilization rate of vehicles, thus improving the overall effectiveness in terms of cost as well as energy intensity. (e.g., see ref. 23).

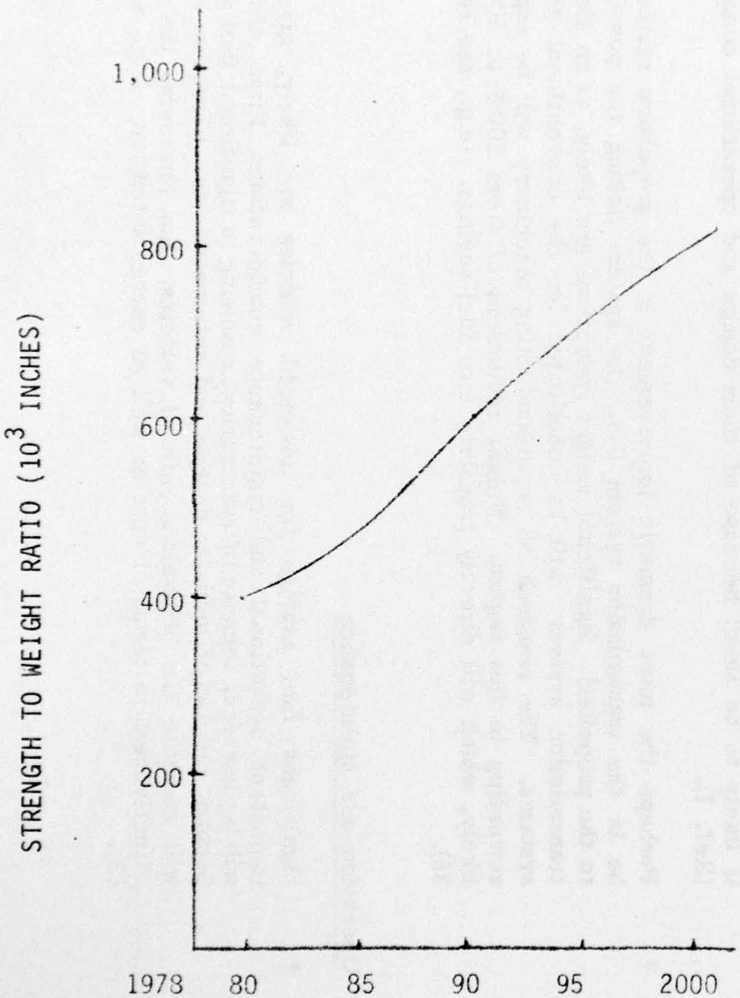


Figure IV-20: Improvement in Material Properties (Applicable to Cutters)

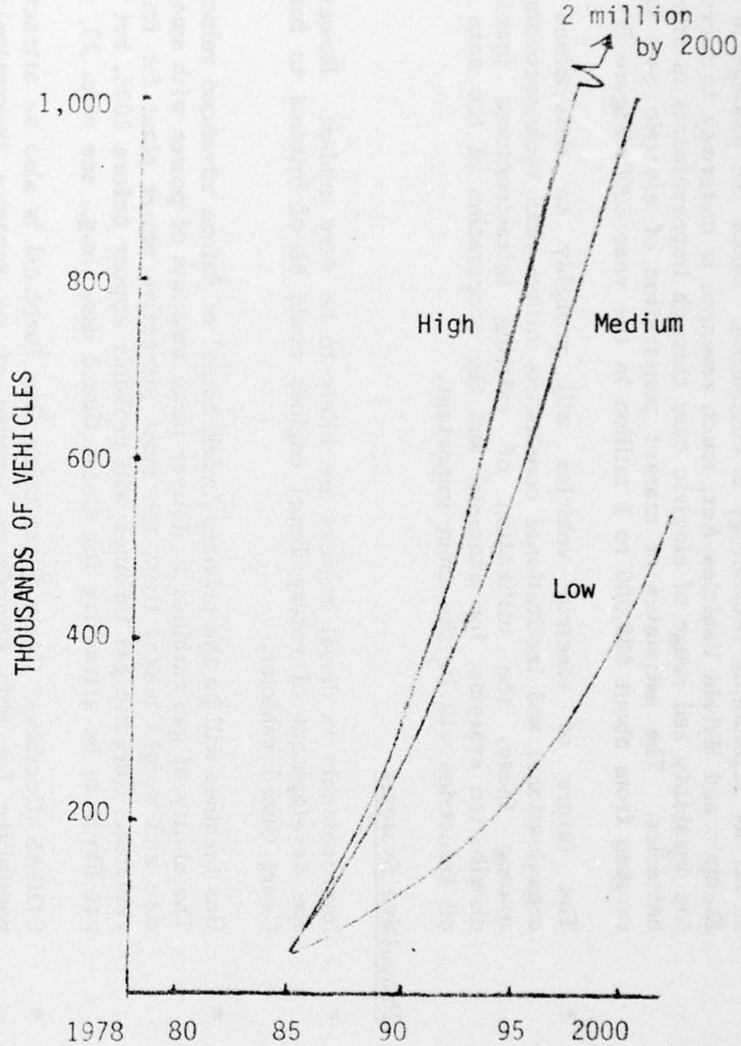


Figure IV-21: Penetration of Electric Cars (U.S.)

Unmanned Vehicles

* Substantial progress has recently been made in the field of unmanned, remotely-piloted vehicles. The unmanned vehicles will be useful to the Coast Guard under at least two circumstances: (a) when human decisions are not essential to effectively carrying out a mission (e.g., performing routine surveillance and environmental protection activities, mapping for marine science, and augmenting the performance of the parent vehicle); and (b) when the environment is hostile (e.g., disposal of dangerous waste materials, or execution of a mission in extreme weather conditions).

* Among the many configurations proposed as unmanned vehicles, the following three look promising: patrol drone aircraft which can increase the search area covered by the parent vehicle; hydrofoil trackers which can be launched from a cutter, giving it a considerable advantage in speed and pursuit of a suspected target ship; and, buoy-based dew lines which can collect and relay information to ships and shore sites. These vehicles were among the many configurations studied by the Futures Group for the Coast Guard. (Ref. 11).

* Technologies needed for operationalizing the unmanned vehicle concepts are currently available. These vehicles can be added to the Coast Guard inventory five to seven years after the decision to utilize them has been made. These vehicles could be operational between 1985 and 1995 (See Table IV-1).

* Technology required for unmanned vehicles is relatively advanced and sophisticated. Use of such technologies will require innovative management by the Coast Guard, particularly in regard to acquisition and operation decisions. Organizational constraints and approaches, rather than the technoeconomic considerations, are likely to influence the use of these technologies.

4. Alternate Fuel and Energy Technologies

As mentioned previously, the following technologies appear promising for this study: synthetic fuels derived from oil shale and coal; and fuel and photovoltaic cells as sources of electric power.

* Current forecasts of market penetration of these fuel and energy technologies are conflicting, and the disparities are taken into account in the forecasts developed for this study. (e.g., see refs. 7, 8, 41, 44).

* All existing Coast Guard vehicles depend upon liquid fuels - diesel, jet fuels, aviation gasoline, motor gasoline, and Navy Ship Fuel Oil (NSFO). These fuels are derived from natural crude oil of differing qualities. Synthetic crude oil, derived from coal and/or oil shale, is a likely future substitute for natural crude oil, although its use could require some modifications in existing refineries.

* We estimate that 500,000 to 1,000,000 barrels/day of synthetic crude oil derived from coal can be made available by 2000 at a production cost of $20 to $30 (1976 dollars) per barrel (Figures IV-22, IV-23).

* We estimate that 300,000 to 1,000,000 barrels/day of synthetic crude oil derived from oil shale can be made available by 2000 at a production cost of $20 to $28 (1976 dollars) per barrel (Figures IV-24, IV-25).

* These estimates show a rapid growth for the synthetic fuels industry, once the first few plants are constructed. Estimates of the time period during which this might happen influence the ultimate growth rate of the industry. In a sense, this is equivalent to determining the 5% to 10% substitution point considered in many substitution models (e.g., Ref. 10). For coal derived synthetic fuels, this point occurs around 100,000 barrels/day plant capacity, while for oil shale it is around 50,000 barrels/day. The ultimate saturation point (the limit line) is sufficiently far enough in the future and, hence, is not reflected in Figures IV-22 and IV-24.

* The cost estimates mentioned above must be <u>cautiously</u> interpreted. At the present time, it is difficult to develop accurate cost estimates for these fuels because of rapidly changing costs of competing fuels and rapid escalation in plant construction costs. However, the estimates in Figures IV-23 and IV-25 provide the likely production cost for these fuels based on current information.

* In comparison to the total U. S. requirements for petroleum products, the above production estimates are small. However, these levels will provide substantial impetus to the development of a vigorous synthetic fuel industry.

* Fuel cells and photovoltaic cells show considerable promise to help meet energy needs of the Coast Guard.

* Fuel cells produce electricity, as well as fresh water as a by-product. This technology is currently well known and established. We estimate that fuel cells can be made available in substantial quantities (125 to 1500 MW) by 2000 at a cost of $300 to $600 (1976 dollars) per KW (Figures IV-26 and IV-27). The rather wide range in the quantity estimates reflect the uncertainty regarding the scale economy of fuel cells.

* Photovoltaic cells convert solar energy into electricity. They will be of special significance to the Coast Guard, particularly in its operations in remote locations. Although the current cost of these cells is prohibitive, it is expected that the economies of scale will permit substantial cost reductions so they will be available in production quantities of 500 to 1500 MW at a cost of $100 to $150 (1976 dollars) per KW by 2000 (Figures IV-28 and IV-29).

* As with the production of oil shale and coal-derived liquid fuels, the production capabilities for fuel cells and photovoltaics remain uncertain because of rapidly changing estimates of production costs and the price of competing fuels. We estimate that a 5% substitution point (Ref. 10) corresponds to 30 MW capacity for fuel cells and 40 MW capacity for photovoltaics. These substitution points are in terms of total capacity which can be displaced by fuel cells and photovoltaic and <u>not</u> in terms of total generating capacity of the U.S.

SYNCRUDE FROM COAL

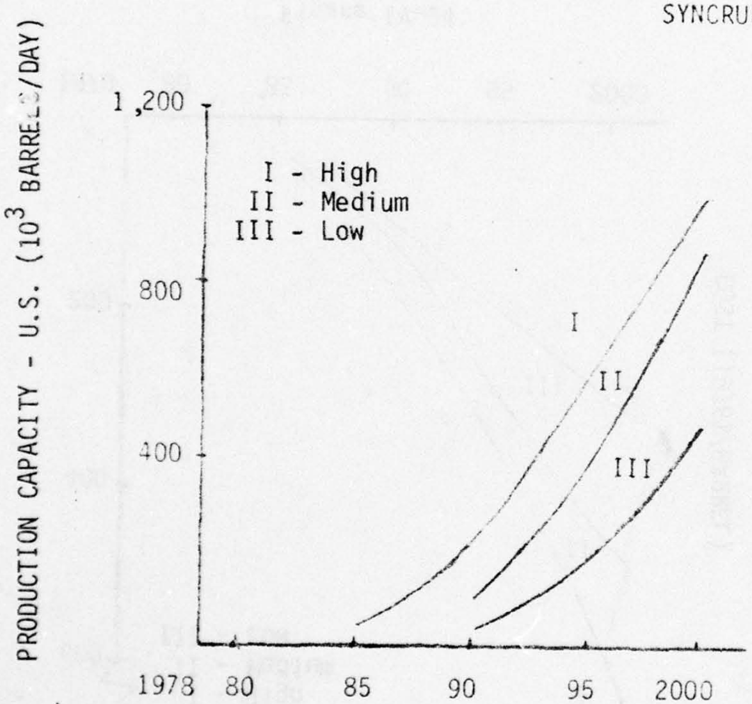


Figure IV-22

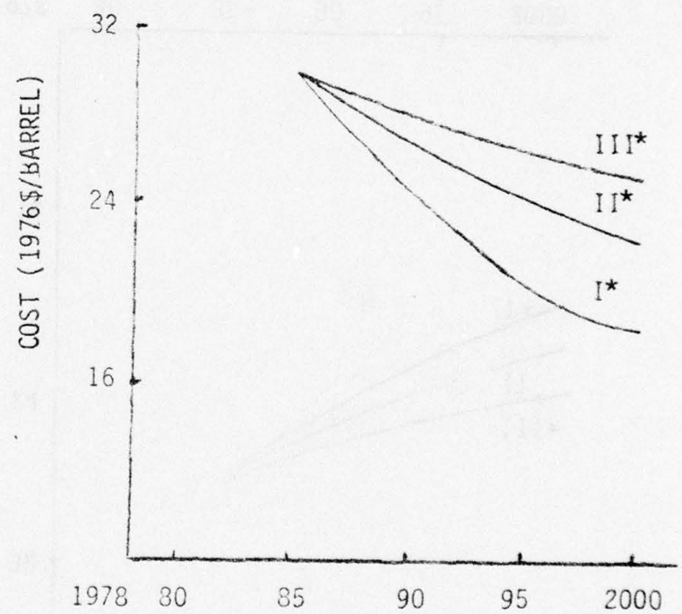


Figure IV-23

* correspond to capacity estimates I, II, III in Figure IV-22

SYNCRUDE FROM OIL-SHALE

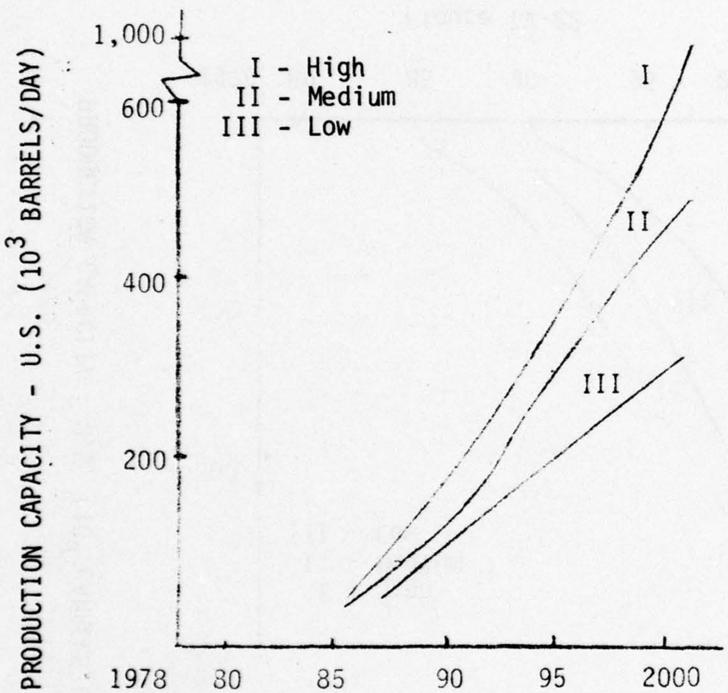


Figure IV-24

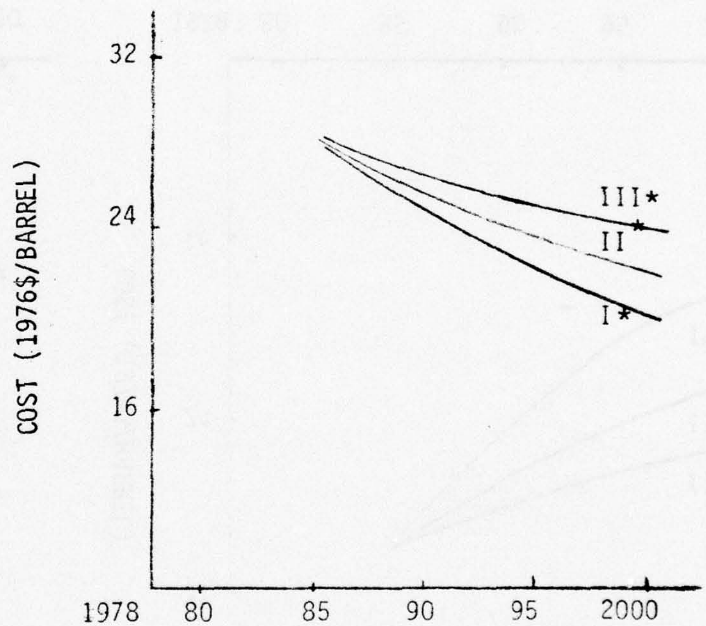


Figure IV-25

* corresponds to capacity estimates I, II, III in Figure IV-24.

FUEL CELLS

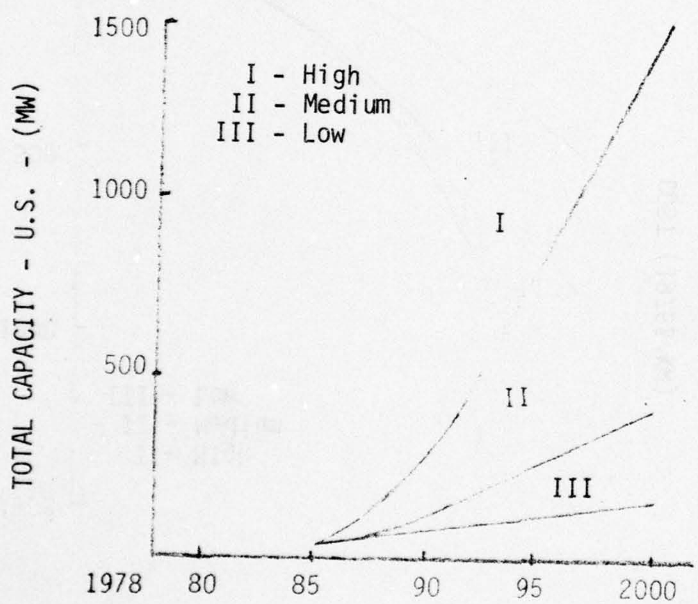


Figure IV-26

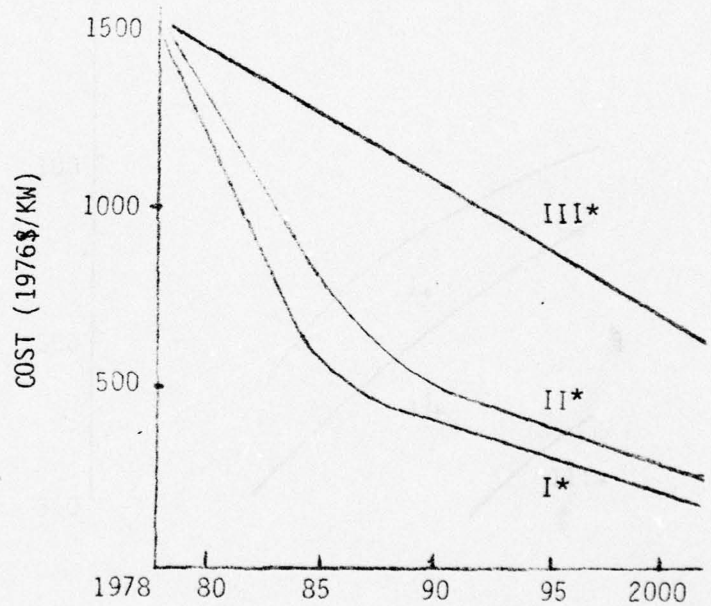


Figure IV-27

* Correspond to capacity estimates I, II, III in Figure IV-26

PHOTOVOLTAIC CELLS

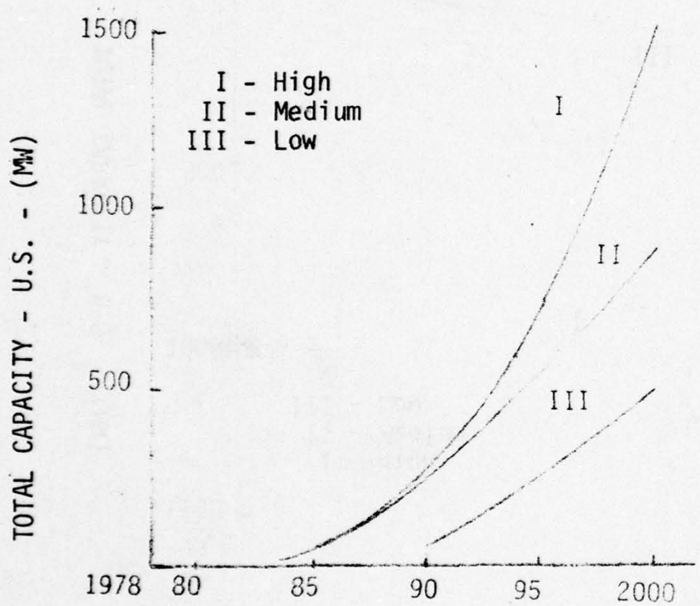


Figure IV-28

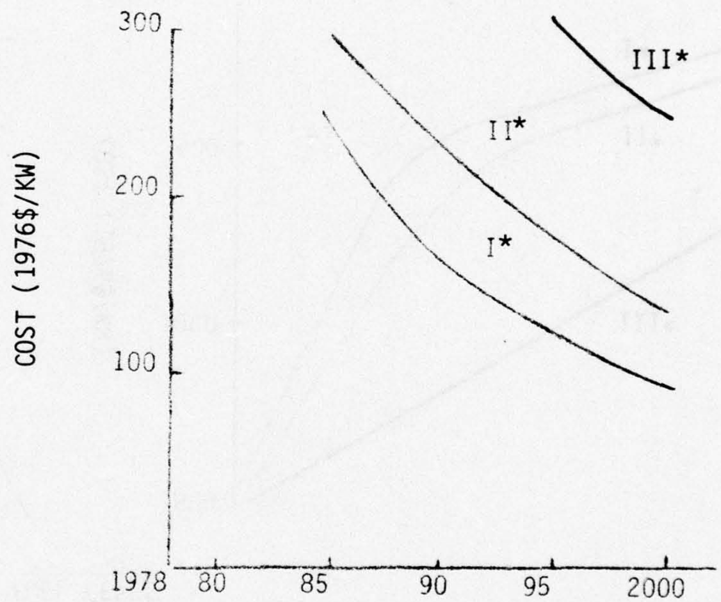


Figure IV-29

* Corresponds to capacity estimates I, II, III in Figure IV-28

* The production cost estimates for fuel cells and photovoltaics should also be cautiously interpreted for the same reasons cited above for synthetic fuels.

5. Non-Vehicle Technologies

Forecasts in this substantially broad area have been limited to a few systems capable of significantly affecting Coast Guard missions and requirements.

* A Maritime Traffic Control System (MTCS), such as the one being offered by Boeing, shows considerable promise in minimizing the number and frequency of surveillance, search, patrol, and mapping missions. Such a system can provide a continuous coverage of all coastal zones of the U.S., including Hawaii and Alaska. Details of one such system can be found in Surveillance of 2,000,000 Square Miles of Ocean, a Boeing brochure.

* A number of remote sensors are now available and have been tested for diverse applications by various agencies, including NASA, which uses them in its Earth Resources Technology Satellite (ERTS) program. (e.g., see ref. 36, Section II). The remote sensors can perform many functions for the Coast Guard, including the identification of pollutants in coastal and inland waters, the mapping of vessels, and the performance of marine science activities. The sensors can be installed on existing Coast Guard aircraft and helicopters. Among the many sensors currently available, the infrared radiometers and imaging devices, synthetic aperture radar, ultra-violet sensors, multispectral scanners, and microwave radiometer appear particularly useful. The technology for these sensors is well established. They can be added to the Coast Guard inventory two to four years after the decision to utilize them is made. Like the unmanned vehicles, the future use of such sensors will be constrained by organizational attitudes toward adopting advanced technologies. Under a favorable organizational climate, these sensors can become operational between 1980 and 1985.

* As a total mission AN (Aids to Navigation) is an energy-intensive mission. Technologies which reduce the servicing frequency, increase the reliability of power sources for buoys, and provide remote monitoring of buoys will help improve the energy efficiency of AN missions. Further, substitution of cutters and tenders by boats can also produce energy savings, although substitution will be somewhat limited by weather conditions. Servicing frequency can be further reduced by optimum scheduling of visits and by increasing the durability of buoys via designs (e.g., plastic buoys). Photovoltaics provide a promising way to increase the reliability of currently used power sources. The monitoring of buoys via shorebased systems or surveillance by aircraft should also be possible. Current use of ANTS (Aids to Navigation Teams) has already increased the efficiency of AN programs. (Ref. 4). Combining of AN in a multipurpose mode rather than the current concept should also lower the energy intensity of these missions.

* The use of training simulators can prepare the crew for performing the mission. For example, the civilian aircraft industry has realized significant fuel economy by utilizing flight simulators. Simulators provide energy savings in two ways: (1) by reducing the need for training flights and missions and (2) by helping the crew to operate the vehicle in an optimum manner. A 1974 FAA study, for example, attributes fuel savings of 24.6 million gallons in the commercial aircraft fleet to the use of flight simulators. (Ref. 45). The simulators teach the crew the best way to respond to a particular mission requirement by adjusting vehicle performance parameters. For example, aircraft speed and altitudes determine aircraft fuel consumption and the fuel consumption of many ships varies approximately as V^3 (V=speed). Thus, operation of aircraft at optimum altitude and speed, and of ships at optimum speed, can produce significant cumulative fuel savings, over a period of time.

D. Sensitivity Analysis

Chapter II described three scenarios of the future which may impact Coast Guard missions and needs. Technology forecasts and their characteristics discussed in the previous sections tacitly assume that the environment in which technologies develop and are deployed resembles that in Scenario X (Surprise Free). In this section, we will examine the impact of significant changes depicted in Scenarios Y and Z of the technology forecasts.

The approach to sensitivity analysis consists of relating the technology parameters to significant changes depicted in Scenarios Y and Z. This means we need to determine if the time of availability of technologies and their characteristics will change in response to conditions delineated in Scenarios Y and Z.

1. Impacts of Scenario Y

Scenario Y is postulated as an external threat scenario. It is characterized by a pronounced increase in coastal threat during the 1980 to 1985 time period. Accordingly, the significance of Enforcement of Laws and Treaties, Marine Environmental Protection, Port Safety and Security, and Military Operations and Military Preparedness missions increases.

The impacts of these conditions can be traced to the following changes in technology forecasts.

* Changes in needs accompanied by budget increases will accelerate the time of availability of certain advanced vehicles, particularly the hydrofoil and surface-effect ships. It will also mean that the use of surveillance vehicles - helicopters, airships, and MRS - will substantially increase.

* The importance of low energy technologies will decrease. Fuel savings will be sacrificed to obtain better performance - speed, range and endurance - from the vehicles. The shift to high performance in lieu of low energy vehicles will be pronounced. Thus, the use and implementation of fuel conserving technologies (e.g., those in Figures IV-7, IV-8) will be delayed.

* The increase in leisure type activities has little impact upon technology forecasts presented in the previous section because the characteristics of the existing Coast Guard vehicles seem capable of responding to any such additional needs. The only exception might be the increase in underwater activities, especially if leisure activities increase significantly in that area. In this case, additional underwater surveillance will increase. A recreation use submarine is already available from one company which has the following characteristics: payload of one person, battery recharging interval-105 minutes, diving depth - 600 feet.

* The importance of MEP missions would mean a shift toward remote sensors and surveillance equipment, which would permit additional fuel to be transferred to other missions, such as ELT and PSS.

* A severe reduction in the availability of imported fuels will accelerate the development of synthetic fuels and alternative technologies.

2. Impacts of Scenario Z

The theme of Scenario Z is internal shifts. This scenario is characterized by significantly increased coastal threat (1990); increased external threats (2000-2005); rising crime rates (1985-1995); increased marine resources activity (1990-2000); and increased Coast Guard budget (1985-2000). The technologies most affected by these changes are those relevant to ELT, MEP, PSS and Polar Ice Operations. The impact of these conditions on technology forecasts will be as follows.

* Availability of technologies which are particularly relevant to ELT and MEP missions will be affected. Particular emphasis will be placed on high performance vehicles such as hydrofoils and remote sensing techniques used to reduce the MEP mission fuel consumption. Airships, attractive for use in both ELT and MEP missions, could prove to be particularly important in this scenario, assuming that they are equipped with appropriate sensors. However, budget increases may be insufficient to procure such vehicles.

* In Scenario Z, low energy technology impacts, will be identical to those in Scenario Y, since both scenarios postulate internal or external threat. Thus, the efforts to implement the fuel saving technologies for vehicles such as HH-3F, HC-130, and cutters would be delayed; the use of other vehicles, e.g., tenders, patrol boats, would increase to balance the overall energy requirements of the Coast Guard.

E. Implications for the Coast Guard

An important question to ask about the technology forecasts discussed in the previous section is: what do they reveal about the future needs and requirements of the Coast Guard? This is a particularly important question since all forecasts are conditional and uncertain, some more so than others. The value of forecasts lies in their ability to provide information and depict alternatives and the basic knowledge required to make intelligent decisions and policies.

We therefore examine the implications in three categories.

1. What do the various forecasts imply for future energy requirements of the Coast Guard?

2. What opportunities are provided by these forecasts are significant to the Coast Guard?

3. What potential future problems should the Coast Guard be aware of now?

Each of these questions is discussed in the subsequent section. Further, Chapter V contains a detailed analysis of energy implications for major Coast Guard vehicles, alternate fuels, and some important Coast Guard missions. That chapter also contains a brief sensitivity analysis of future energy consumption.

1. Implications for Future Energy Requirements of Existing Vehicles

We do not attempt here to develop comprehensive forecasts of energy requirements, as this would require a detailed study of individual missions and vehicle use, an effort which is beyond the scope of this study. For a partial forecast of the energy demand see Chapter V-F. We present here projections based on varying rates of growth in fuel requirements, for cutters, boats, and aircraft. The baseline data (i.e., for 1974-1975) uses the Tetra Tech study (Ref 42). Since we employ assumptions regarding growth rates in fuel use, the accuracy of the Tetra-Tech data is not critically important to our analysis.

The approach used to estimate fuel savings for existing vehicles consists of the following steps:

(a) estimating fuel requirements for 1990 and 2000 separately for cutters and aircraft;

(b) assuming different rates of adoption of fuel saving technologies, as depicted in the forecasts for existing vehicles. This is done by specifying alternate schedules for equipping the existing vehicles with the fuel saving technologies over the 1980-2000 time period;

(c) estimating the fuel savings for cutters and aircraft.

Although the analysis considers only existing vehicles, it is useful because it illustrates the magnitude of the impact technologies have on the Coast Guard's energy consumption and it yields a range for fuel saving potential since the future (1980-2000) Coast Guard fleet is likely to be dominated by existing vehicles.

Application of these steps yields the estimates shown in Tables IV-2, IV-3, and IV-4. Fuel requirements for 1990 and 2000 are derived by assuming three different growth rates (annual constant rates of growth between 1975 and 2000) for cutters, and two different growth rates for aircraft. Estimates for fuel savings are based upon technology forecasts presented in the previous section, but assume the median estimate shown there (e.g., in Figure IV-8 for aircraft).

TABLE IV-2

ESTIMATES OF FUTURE FUEL REQUIREMENTS

(10^3 Gallons)

	ANNUAL CONSTANT GROWTH RATE				
	CUTTERS			AIRCRAFT	
	2%	5%	10%	3%	5%
FUEL CONSUMPTION					
1990	51,362	69,141	98,772	19,643	23,707
2000	59,264	88,895	138,282	23,707	30,481

* 1974 fuel consumption was: 31,134 x 10^3 gallons by Cutters (Ref. 42)
12,196 x 10^3 gallons by Aircraft (Ref. 42)

1975 fuel consumption was: 39,509 x 10^3 gallons by Cutters (Ref. 42)
13,547 x 10^3 gallons by Aircraft (Ref. 42)

TABLE IV-3

IMPACT OF LOW ENERGY TECHNOLOGIES (LET)

CUTTERS

	% of Existing Cutters Equipped with LET in		FUEL SAVINGS (10^3 Gallons)					
			1990			2000		
SCHEDULE	1990	2000	2%	5%	10%	2%	5%	10%
A	25	100	513	693	988	4,740	7,110	11,062
B	10	75	205	277	395	3,555	5,332	8,297
C	0	50	0	0	0	2,370	3,555	5,531
D	0	25	0	0	0	1,185	1,778	2,766

TABLE IV-4

IMPACT OF LOW ENERGY TECHNOLOGIES (LET)

AIRCRAFT

	% of Existing Aircraft Equipped with LET in		FUEL SAVINGS (10^3 Gallons)			
			1990		2000	
SCHEDULE	1990	2000	3%	5%	3%	5%
A	25	100	245	296	1,185	1,524
B	10	75	98	118	889	1,143
C	0	50	0	0	593	762
D	0	25	0	0	296	381

Table IV-3 and IV-4 indicate that fuel savings are dependent upon assumed growth rates and the schedule for equipping existing cutters with low energy technologies. Four different schedules are assumed for equipping the vehicles with Low Energy Technologies. Schedule A specifies that 25% of the cutters and aircraft will be equipped with Low Energy Technologies by 1990, and in 2000 the number will increase to 100%. Schedule D, on the other hand, specifies that only 25% of the cutters and aircraft will be equipped with Low Energy Technology by 2000 with none so equipped by 1990. Schedules B and C are intermediate cases to schedules A and D.

The annual fuel savings range from a low of 205,000 gallons in 1990 to 11,062,000 in 2000, which corresponds to the vehicle mix equipped with low energy technology as 10% and 100% of the total vehicles. Assuming that cutters use diesel costing 65 cents per gallon, the savings range from 0.13 to 7.1 million dollars per annum. Assuming a 30 year life for cutters and no escalation in diesel costs (a very optimistic assumption), savings could amount to 3.9 to 213 million dollars, over their service life. On the other hand, if we assume that diesel fuel cost will increase at least at the inflation rate, the savings will be substantially higher.*

For aircraft, savings range from 98,000 gallons to 1,524,000 gallons. Assuming that jet fuel cost is 60 cents per gallon, savings per annum amounting to $60,000 to $914,000 would result. If the service life of aircraft is assumed to be 25 years, the savings would amount to $1.5 to $23 million . Again inflating jet fuel cost (a more realistic case), the savings would be much greater. In either case, the savings are substantial.*

It also should be noted that fuel savings amount to as much as 8% of the total fuel requirements for cutters in the year 2000 under the most optimistic schedule; for aircraft, the figure is about 5%. These savings are based on utilizing low energy technology for existing cutters and aircraft. When the impacts of other low energy technologies are considered, the savings would substantially increase. It is this fact that leads us to believe the potential for savings may be as high as 20% to 30%.

2. Promising Opportunities

Technology forecasts indicate opportunities which the Coast Guard can consider. Among the most promising ones are the following:

* Many opportunities to conserve fuels are available. Improved maintenance procedures, improved engine design, and reduced weight are some of the simple, but promising, energy conserving techniques. Deployment of such technologies, however, could make the Coast Guard activities more labor intensive. In this connection, we note that the Coast Guard is undertaking programs to improve the efficiency of boilers and engines on some of its cutters.

---

* The Coast Guard Annual Report of Energy Management, June, 1979, contains estimates of fuel consumption for FY1978 for cutters and aircraft. The work reported here was completed prior to June, 1979. However, if FY1978 data are used as the starting point (instead of FY1975 data as we have used here), the estimated savings are approximately as follows: (See continuation of footnote on following page).

* Tactical changes would also lower energy consumption. Two performance parameters are especially important in this regard - choice of vehicle speed and altitude at which aircraft are flown. It should be noted in this connection that the Coast Guard is taking steps to reduce jet fuel consumption by using JETPLAN at four air stations for C-130 operations. JETPLAN identifies an efficient route to reduce the consumption, in terms of weather conditions, fuel load, and altitude.

* A number of new systems hold considerable promise for energy savings. The development of such systems must be closely monitored. Among these are: the design of more efficient propulsion transmission systems; the use of improved structural materials for Coast Guard platforms, including aircraft, (e.g., composites, reinforced plastics); the development of more efficient engines, particularly the regenerative types; and the development of gas turbine technology, particularly the use of ceramics to reduce heat rates.

* New/advanced vehicles, particularly airships and SWATH Ships, could provide opportunities for improving mission performance and lowering energy consumption. The Coast Guard should actively monitor the development of these vehicles and emphasize the design characteristics that maximize the energy efficiency of the vehicle to the fullest extent possible.

* Energy savings can be influenced through weight reduction. Among the parameters important in reducing weight are: crew size, fuel tankering practices, and ship size. Administrative procedures can influence the first two parameters. Design of small, high-performance ships needs to be pursued vigorously. (e.g., see refs. 2, 19, 21, 23, 30).

* Photovoltaics and fuel cells hold considerable promise for Coast Guard use. Photovoltaics can be used both on remotely located platforms (e.g., AN) and on ships as a power source. As noted earlier, the Coast Guard is experimenting with photovoltaic cells on some of its equipment on the Atlantic coast. The fuel cell is another technology which shows considerable promise because it produces both water and electricity. The Coast Guard needs to undertake programs to further explore the potential uses of these technologies.

* Dependence of the Coast Guard on liquid fuels will undoubtedly continue over the next 25 years. The price of these fuels will also rise, rapidly at times. The availability of alternate liquid fuels, particularly those derived from coal and oil shale, will depend upon the public and private sector commitment needed to accelerate their commercialization.

(footnote continued from preceding page).
(a) For cutters, annual fuel savings range from a low of 22 billion Btu in 1990 to a high of 1,114 billion Btu in 2000, or 159,000 to 8,032,000 gallons of diesel fuel assuming an average value of 138,700 Btu per gallon. Corresponding dollar savings per annum are 0.1 and 5.2 million. Over the life time of cutters, assumed to be 30 years, the dollar savings amount to a low of 3.1 and a high of 157 million dollars.
(b) For aircraft, annual fuel savings range from a low of 18 billion Btu in 1990 to a high of 273 billion Btu in 2000, or 138,000 to 2,100,000 gallons of jet fuel assuming an average value of 130,000 Btu per gallon. Corresponding dollar savings per annum are 83,000 and 1,260,000. Over the lifetime of aircraft, assumed to be 25 years, the total savings amount to a low of 2.1 and a high of 31.5 million dollars.

* It seems to us that it is possible for the Coast Guard to become nearly self-sufficient in its fuel supply. We note that the Coast Guard's fuel usage is fairly evenly distributed east and west of the Mississippi. Based on 1975 estimates contained in the Tetra Tech study (Ref. 42), the percentage of total fuel used is distributed as follows:

Eastern and Southeastern districts: 51.8%
Midwestern states: 6.9%
Western States: 15.7%
Alaska: 17.2%
Hawaii: 8.3%

If these patterns of fuel usage are correct and expected to hold in the future, the Coast Guard can design a strategy to become almost self-sufficient for its fuel needs with the exception of Hawaii. Such a strategy will consist of:

(a) constructing a small complex, producing synthetic fuels derived from Appalachian coal, with 5000 barrels/day capacity. This plant could serve Coast Guard needs for the eastern and southeastern districts;

(b) constructing an oil-shale plant in either Colorado or Utah to supply its midwestern and western needs. Opportunities probably exist to work jointly with the Navy to produce oil from Naval Oil Shale Reserves in Colorado;

(c) constructing a small refinery in Alaska for supplying its Alaskan needs, using Alaskan crude.

The only district which will then be dependent upon conventional crude would be Hawaii, which can be supplied from California refineries using Alaskan crude.

We realize that this suggestion is extraordinary, unconventional, and could be quite expensive. However, the benefits of a secure fuel supply are very important and cannot always be quantitively measured, particularly in terms of scarcity and possible hostilities (as depicted in Scenarios Y and Z). For this reason, it merits Coast Guard consideration.

* Finally, opportunities to develop total energy systems also exist. This concept is more fully presented in Appendix E.

3. Future Problems

Based on an evaluation of technology forecasts, we note a number of potential problems which may face the Coast Guard.

* New/advanced vehicles are unlikely to be designed to maximize their energy efficiency. (The airship, of course, is an exception under certain conditions). The energy consumption of these new/advanced vehicles is likely to be determined by the manner in which they are used, i.e., matching mission requirements with vehicle performance at all times will be a significant factor determining the vehicle's energy efficiency.

* Further, the Coast Guard has little influence over the design of new vehicles which are being developed primarily by the Navy or the private sector. The airship is especially likely to suffer from this situation. In the process of developing forecasts, we have noted little current DOD interest in developing airships, except by a few entrepreneurs and by NASA, to some extent. Westinghouse, for example, is developing a communication system for Nigeria using airships as communication platforms. However, estimating the potential of such concepts will require a separate analysis.

* Lead times to implement most of the low energy vehicle concepts, range from 3 to 10 years. Such lead times require an early commitment by the Coast Guard.

* The use of some of the low energy technologies have significant implications for labor requirements - both in terms of quantity and skills. For example, improved maintenance procedures will often require additional skilled personnel, as will the deployment of advanced vehicles, communication and navigation systems. Because of current concerns about recruitment, this factor may become especially critical to the Coast Guard.

* Further, the use of low energy technologies will require changes in the administrative procedures, management practices, and dissemination of information. Organizational inertia and constraints may well pose problems in this area. (See also Chapter VI on Organizational Issues).

* We believe that an energy information system which can track energy use and fuel supply on a real time basis is a dire necessity for the Coast Guard. In the era of scarce fuel, it seems essential that the Coast Guard be able to monitor its energy use accurately and attempt to obtain the maximum from every unit of energy expended in performing missions. To our knowledge, the Coast Guard is currently developing an energy information system in two phases. Phase 1, dealing with data collection, checking, and formating is nearing completion. However, the Phase 1 data are not expected to specify the energy use for individual activities constituting a mission, or the fuel use patterns of individual vehicles used in a mission, particularly in terms of tactical parameters such as the speed profile of the vehicle over the mission duration.

  Our concept of an energy information system, although conceptually akin to that of the Coast Guard, is more comprehensive and structurally different. It consists of the following three major components:

  1. <u>An Energy Accounting/Auditing System</u> which will collect, interpret, and audit information for completeness and comprehensiveness, maintain the data base; and, prepare information in a suitable format for the users' needs.

  2. <u>Energy Flow Networks</u> which will structure the information generated by the energy accounting/auditing systyem. Two types of networks seem necessary. One network shows the flow of energy from the various sources to the various end uses such as the vehicles. The second network shows the flow of energy during a mission, in terms of various activities constituting the mission and the vehicles used to perform the mission activities.

3. Analysis and Interpretation of the energy accounting/auditing system and the energy flow networks to produce information for two purposes: first, information to relate the changes in energy requirements and supply characteristics to the major activities and functions of the Coast Guard; and, second, information to provide the basis for estimating the future energy requirements of the Coast Guard.

In terms of the structure comprising these three components, it appears that Phase 1 of the Coast Guard's planned energy information system, albeit very important, pertains only to the energy accounting/auditing system component delineated above.

* We anticipate the Coast Guard's continued dependence upon conventional petroleum products for much of this century. Further, we note that the Coast Guard fleet is likely to be dominated by the existing vehicle mix. Consequently, technologies to lower energy consumption discussed in section B-1 become especially important. Although the impact of such technologies will depend upon the Coast Guard's ability to implement them on the most feasible schedule, we think that the vulnerability to oil supply interruptions may remain substantial in the near future, and would recommend an analysis of this vulnerability in terms of parameters such as the elasticity of major missions. (e.g., see ref. 38).

* It is tempting to derive comfort from an observation that the Coast Guard is a relatively small user of energy. However, with the price of petroleum products likely to continue to rise and possibility of supply interruptions, a shortage could well occur. Such events will put strains on supply quantities available for performing Coast Guard missions unless the budget is keyed to the price of petroleum products. With anticipated increases in the price of fuel and number of missions in the future, the supply problem is likely to be grave. Prudent anticipatory planning by the Coast Guard seems to be the only way to avoid future regrets.

REFERENCES

1. Abbot, J. W., et al., A Dynamic Analysis of COGAS Propulsion Plant, Naval Engineer's Journal, December 1977.
2. Adler, R. E., "In the Navy's Future: The Small Fast Surface Ship", U.S. Naval Institute Proceedings, March 1978.
3. Beatty, R. E., et al., Assessment of Selected Lighter-Than-Air Vehicles for Mission Tasks of the U.S. Coast Guard, A report prepared for the U.S. Coast Guard, March, 1978.
4. Booz Allen Applied Research Inc., Servicing System for Short-Range Aids to Navigation, A report prepared for U.S. Coast Guard, November 7, 1970.
5. Clark, D. J., et al., "Balancing Mission Requirements and Hydrofoil Design Characteristics", AIAA/SNAME Advanced Marine Vehicles Conference, April 17-19, 1978.
6. Davis, S. J. and Rosenstein, H. J., Identifying and Analyzing Methods for Reducing the Energy Consumption of Helicopters, report prepared for NASA by Boeing Vertol Company, December, 1976.
7. Dickson, E. M., et al., Impacts of Synthetic Liquid Fuel Development -Automotive Market, Volumes I, II, and III, report by Stanford Research Institute for ERD & EPA, July, 1976.
8. Electric Power Research Institute, Supply 1977, March, 1978.
9. Fickett, A., "Clean Power for the Cities", EPRI Journal, November, 1978, pp. 6-12.
10. Fisher, J. and R. Pry, "A Simple Substitution Model of Technological Change", Technological Forecasting and Social Change, 1971
11. Forecasting International Ltd., An Analysis of The Relevant Factors and Forecasts of Events Affecting the U.S. Offshore Management and Security in 200 Mile Zone, prepared for the U.S. Coast Guard.
12. The Futures Group, A Morphological Analysis of Unmanned Vehicles, prepared for the U.S. Coast Guard, September, 1978.
13. Jewell, D. A., Energy Efficiency of Sea and Air Vehicles, U.S.C.G. Report no. CG-D-15-19, August, 1978.
14. Justus, C. G., Winds and Wind System Performance, the Franklin Institute Press, 1978.
15. Gray, D. E., Study of Turbo-Fan Engines Designed for Low-Energy Consumption, Pratt and Whitney Aircraft, April, 1976.
16. Hamilton, T. M., et al., Technical and Operational Characteristics of High Performance Water Craft, report prepared for the U.S. Coast Guard, February, 1975.
17. Hawkins, S., et al., "Hydrofoil Operational Performance Enhancement using Hybrid Design Options", AIAA/SNAME Advanced Marine Vehicle Conference, San Diego, CA, April 17-19, 1978.
18. Huang, C. J., et al., Cargo Transportation by Airships: A Systems Study, University of Houston, Texas, May, 1976.
19. Hessman, J. D., "The Small Ships", Sea Power, September, 1976.
20. "Jane's All the World's Aircraft", "Jane's Fighting Ships", "Jane's Surface Skimmers", McGraw Hill Company, New York, Various Editions.
21. Kennel, C. G. and T. A. Anderson, Small Waterplane Area Twin Hull (SWATH) Combatant Ship Parametric Study, A report by Naval Ship Engineering Center, September, 1978.
22. Lamb, R. G., The SWATH Concept: Designing Superior Operability into a Surface Displacement Ship, Naval Ship Research and Development Center Report, December, 1975.

23. Leopold, R., "Technology and Future Warship Design", U.S. Naval Institute Proceedings, March, 1978.
24. Linstone, H. A., and D. Sahal, (editors), Technological Substitution: Forecasting Techniques and Applications, Elsevier-North Holland, 1976.
25. Mandel, P., Water, Air, and Interface Vehicles, First Edition, MIT Press, 1969.
26. Report of MIT Vehicle Technical Assessment Project, MIT, July, 1977.
27. Marchetti, C., and N. Nakicenovic, The Dynamics of Energy Systems and the Logistics Substitution Model, a report by International Institute for Applied Systems Analysis, July, 1978.
28. Martino, J. P., Technological Forecasting for Decision Making, Elsevier-North Holland, 1972.
29. Martino, J. P., and S. K. Conver, "The Stepwise Growth of Electric Generators Size", Technological Forecasting and Social Change, 1971.
30. Meyer, J. R., Jr., and J. H. King., "The Hydrofoil Small Waterplane Area Ship (HYSWAS)", AIAA/SNAME Advanced Marine Vehicles Conference, Arlington, Virginia, September 20-22, 1976.
31. Mikolowsky, W.T., et al., An Evaluation of Very Large Airplanes and Alternative Fuels, a report by Rand Corporation for the USAF, December, 1976.
32. Mikolowsky, W.T. and L. W. Hoggle, The Potential of Liquid Hydrogen as a Military Aircraft Fuel, February, 1976.
33. Mitchell, T.R., et al., The Utility of High Performance Water-Craft for Selected Missions of the U.S. Coast Guard, Prepared for the U.S. Coast Guard, November, 1972.
34. Hydrofoils for the Fisheries Law-Enforcement Missions of the U.S. Coast Guard, Volumes I and II, reports prepared for the U.S. Coast Guard, July, 1975.
35. Moore, C. G. and H. P. Pomrehn, "Technological Forecasts of Marine Transportation Systems 1970-2000", Technological Forecasting and Social Change, 1971.
36. National Aeronautics and Space Administration (NASA), A Forecast of Space Technology 1978-2000, January, 1976.
37. NASA Office of Aeronautics and Space Technology, Aircraft Fuel Conservation Technology, A Task Force Report, September, 1975.
38. Naval Weapons Engineering Support Activity, A Prediction of Aviation Logistics Requirements for the Decade 1985-1995, June, 1978.
39. Prichett, C. W., et al., Cutter Resource Effectiveness Model, Volume I, II, reports prepared for the U.S. Coast Guard, June, 1977.
40. San Ramon D. J., and Lorezel D.M., "ACV Icebreaking Operations", Coast Guard Engineering Digest, Winter, 1978.
41. Steele, R., K. Sharma, and E. M. Dickson, Synthetic Liquid Fuels Development, Assessment of Critical Factors, Volume IV: Energy and Economic Comparison of Coal-Based Automotive Energy Supply Systems, a report by ERDA by Stanford Research Institute, May, 1977.
42. Tetra Tech Inc., U.S. Coast Guard Energy Research and Development Program Plan, Volume I and II, Reports prepared for the U.S. Coast Guard, August, 1975.
43. United Aircraft Research Laboratory U.S. Ocean Shipping Technology Forecasts and Assessment, a report prepared for Maritime Industry Administration, July, 1974.
44. University of California, Berkeley, et al, Distributed Technologies in California's Energy Futures, Volumes I and II, reports prepared for the Department of Energy (DOE) by Paul Craig et al, March, 1978.

45. U.S. Department of Transportation, Federal Aviation Administration (FAA), Report to U.S. Congress by the FAA on Proposed Programs for Aviation Energy Savings, April, 1978.
46. U.S. Department of Transportation, Energy Conservation in Transportation. (Date of publication unavailable).
47. U. S. Department of Transportation, The U.S. Coast Guard: Its Missions and Objectives. U.S. Government Printing Office, 1977.
48. Warner, W. L, et al., "Upgrading an Ancient Art - Research and Development Toward Modern Wind Powered Cargo Ships", paper presented at the spring meeting of STAR Symposium, March 25-27, 1977.
49. Williams, C., et al., Emerging Environments, Roles and Activities of the U.S. Coast Guard to 2000 A.D., a report prepared for the U.S.C.G., May, 1977.
50. Winters, H., "Small Cutters for the 21st Century", Coast Guard Engineering Digest, Winter, 1978.

V. ENERGY ANALYSIS

A. Scope of Analysis

The energy analysis can be performed in a number of ways and at different levels of aggregation. Therefore, the specification of the boundaries of the energy analysis is quite important.

For this study, it is essential that the analysis answer the following questions:

1. If energy efficiency is the prime consideration, what are the relative merits of the major existing and future Coast Guard vehicles?

2. How do alternative fuels, especially those derived from coal and oil shale, compare from an energy efficiency perspective?

3. What are the relative merits of various vehicles in performing some representative Coast Guard missions, considering both the energy requirements and some measure of mission performance?

In other words, we move from the issue of energy efficiency of individual vehicles and alternate fuels to the broader issue of mission performance (i.e., choice of tactics) in an energy efficient manner.

Accordingly, the analysis is organized at three levels:

Level 1 analysis consists of comparing the most relevant existing, and a few future, Coast Guard vehicles by considering parameters representative of energy efficiency and use.

Level 2 analysis consists of performing a "net energy analysis" or "energy accounting" of alternative fuels.

Level 3 is an aggregated energy analysis of some selected, but representative, Coast Guard missions. A series of scenarios is developed, depicting the situations and events over the 1980-2000 time period requiring responses by the Coast Guard . Each scenario delineates tactics used by the Coast Guard to respond to a specific situation with alternative vehicles (existing and new/advanced).

The three levels of analysis produce insights concerning the three major components of the LES (Low Energy Setting). As shown in Figure V-1, Level 1 primarily addresses the energy efficiency of existing and new vehicles. Level 2 is related to the second component of the LES, while the Level 3 analysis reveals the impacts of various tactics for performing a mission, taking into account energy requirements as well as an appropriate measure of mission performance (for example, response time in the rescue task of the SAR mission). Considering energy requirements along with measure of mission performance is essential because rarely, if ever, will one be able to simultaneously maximize the performance and minimize the energy requirements; rather, trade-offs between energy requirements and mission performance must be explored and the analysis is designed to shed light on the extent and the nature of trade-offs.

FIGURE V-1

RELATIONSHIP OF THREE LEVELS OF ANALYSIS AND LOW ENERGY SETTING

ANALYSIS	MAIN COMPONENTS OF LOW ENERGY SETTING			
	Existing and Near-Term Vehicles	New/Advanced Vehicles	Alternate Fuels and Energy	Non-Vehicle Technologies
LEVEL 1	X	X		
LEVEL 2			X	
LEVEL 3	X	X		X

Following the three level analysis, we briefly address the question of total energy use. A sensitivity analysis is performed to determine the bounds of future energy consumption based on three vital missions - ELT, SAR, and MEP - and the three scenarios. Such calculations suggest that it will prove exceedingly difficult to reverse the trend of the past decade in growth of total energy use, particularly if ELT becomes the primary Coast Guard mission.

B. Level 1 Analysis: Comparison of Some Coast Guard Vehicles

A vehicle can be compared with other vehicles along several dimensions: design characteristics (weight, speed, endurance, range, cost, size, Froude number, etc.); operational characteristics (energy consumption, operation and maintenance cost, reliability, etc.); and, performance characteristics (response time, capability to operate in adverse environments, etc.). An equitable comparison of various vehicles requires their evaluation along such dimensions. Generalized statements about the superiority of a particular vehicle are not possible. For example, a vehicle may appear to be superior from the point of view of energy efficiency and use but may be quite poor from the point of view of response time. Different dimensions of the evaluation process - alternative frames of reference - should be considered before reaching any conclusions about vehicle superiority. Since this study is concerned primarily with energy, our approach has been to consider measures representative of energy efficiency as well as design and performance characteristics, to the extent possible.

The Level 1 analysis focuses on comparing a few representative vehicles along the dimensions of energy, design and performance. We could not possibly include all of the Coast Guard vehicles in the Level 1 analysis. Rather, we have included in the set at least one vehicle which is used in one or more major missions. Accordingly, the vehicles considered are: HC-130 (fixed wing aircraft), HH-3F and HH-52 (helicopters), WHEC-378 (high endurance cutter), WMEC-210 (medium endurance cutter), MLB-44 (motor boat), WPB-95 (patrol boat), WLM (coastal tender), two LTAV (lighter-than-air vehicles) with 1000 and 2000 mile ranges, two hydrofoils (Jetfoil and Flagstaff), SWATHS, ACV and SES. The principal characteristics of these vehicles are shown in Table V-1. Data in this table were compiled from Coast Guard documents and studies. For example, Jewell (Ref. 3) presents considerable data, in a consistent format, in Appendix A of his report. The LTAV specifications are for 80 knot airships considered in a CNA study for the Coast Guard. The characteristics of SWATH, ACV and SES were selected from the literature using judgements regarding the size most relevant to the Coast Guard missions. It must be stressed that the characteristics of these new vehicles are not firmly established; however, the estimates used here appear representative enough for our analysis. Further, the fuel consumption data shown in Table V-1 are at the indicated speed and must be considered as approximate, since varying assumptions about factors such as the weather conditions and mission parameters (e.g., flight altitude of aircraft) could yield estimates other than those shown here. Also, data on fuel consumption could differ if derived on the basis of total fuel used and total resource (operation) hours. However, the data seem quite adequate for the purposes of Level 1 analysis.

TABLE V-1

CHARACTERISTICS OF CG VEHICLES CONSIDERED

Vehicle	Weight (Tons)	Length (Feet)	Maximum Speed (Knots)	Fuel Consumption (Gallons/Hr)
HC-130	87.5	98.75	290	660
HH-52	4.2	62.3	90	90
HH-3F	11	73	125	186
LTAV(1000)	16	271	80	93
LTAV(2000)	32.5	354	80	144
WHEC-378	3,416	378	29	2,514
WMEC-210A	1,086	211	18	315
MLB-44	19.8	44	16	42
WPB-95	117.6	95	21	135
WLM(175)	1,085	175	12	80
ACV	170	133	50	715
SES	250	150	60	875
Hydrofoil				
--Jetfoil	115	90	46	609
--Flagstaff	84	87	48	262
SWATH Ship	3,000	275	20	770

1. <u>Comparison Among Coast Guard Vehicles.</u>

For each vehicle we consider alternate frames of reference to assess its relative merits. Each frame of reference consists of two dimensions: energy efficiency and use, and an indicator of vehicle performance. Two alternative indicators of energy efficiency have been chosen: transport efficiency or specific resistance, and specific energy which was recently proposed by Jewell in a study for the Coast Guard (Ref. 3). For the second dimension, two parameters are chosen: measure of performance, speed or the response time; and, measure of vehicle design, Froude number.

Transport efficiency of a vehicle is defined as $T = \frac{WV}{P}$

where W = weight of the vehicle (lbs)
V = speed (ft/sec)
P = power (ft-lb/sec)

Transport efficiency thus represents the ability of a vehicle to do work per unit power input. Specific resistance is the inverse of transport efficiency, and indicates energy required to move a vehicle of a given momentum. Specific resistance can also be transformed to estimate energy expended to move a vehicle of unit weight over a mile. Transport efficiency and specific resistance express, in alternate ways, the vehicle's ability to use the power supplied by the engines to do work. Transport efficiency can also be written as the product of propulsive efficiency and lift-drag ratio.

The importance of the relationship between specific resistance (or transport efficiency) and speed is due to the work of Gabrielli and Von Karman. In their much quoted paper, "What Price Speed...", they pointed out that an overall limit line exists for the minimum value of specific resistance of all vehicles. The position of the limit line changes as the vehicle technology improves. Figure V-2, based on Mandel (Ref. 5), illustrates the remarkable relationships of various vehicles.

The specific resistance-speed relationship, however, does not explicitly consider the vehicle design parameters, although it can be argued that speed is dependent upon the vehicle design. An alternate way is to consider the parameter such as Froude number, defined as:

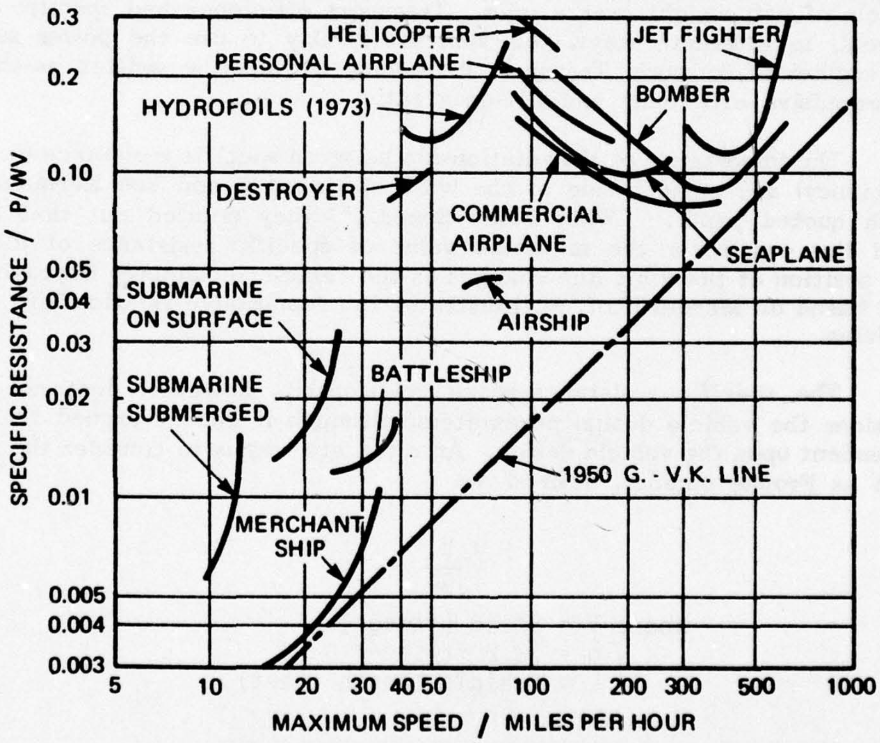
$$F = \frac{V}{\sqrt{gL}}$$

Where V = Speed (ft/sec).
g = 32.2 ft/sec^2
L = Vehicle Length (Feet)

It can be seen that F combines the two vehicle parameters V and L, and can be used to differentiate among dissimilar vehicles from a vehicle design point of view. Thus ships and boats have lower F values while airplanes have higher F values. The F values for space vehicles are extremely high.

FIGURE V-2

SPECIFIC RESISTANCE OF SINGLE VEHICLES



The concept of specific energy is proposed by Jewell in a recent study for the Coast Guard, "Energy Efficiency of Sea and Air Vehicles" (Ref. 3). He defines specific energy as:

$$\left[\frac{1}{2} \frac{WV^2}{g} \right] / \left[\frac{1}{2} (P+TV) \sqrt{L/g} \right]$$

where T is thrust in lbs, and all other terms are as previously defined. T is considered only for jet powered craft when T is more meaningful than P. If P is used, T = 0, and vice versa. Simply put, specific energy is the ratio of energy output (kinetic energy) to energy input (power delivered over some time $\sqrt{L/g}$).

The following frames of reference are then used to compare the vehicles:

speed - transport efficiency,
Froude number - transport efficiency,
speed - specific energy,
Froude number - specific energy.

In addition, the energy efficiency of Coast Guard vehicles, computed as Btu per ton-mile, is compared with that of other modes of transportation. Figures V-3, V-4, V-5, and V-6 show the relationships for the vehicles considered in this analysis.

To interpret the information contained in these figures, note that the higher values of transport efficiency and specific energy imply more energy efficient vehicles, although the comparison must be made cautiously for several reasons. First, the comparison is more meaningful when it is restricted to a particular class of vehicles; i.e., air, sea, etc. Second, simplistic interpretation of higher values of transport efficiency and specific energy, especially as a function of speed, can be misleading since speed is not the only parameter which can be used to measure vehicle performance. Froude number is perhaps more useful from a design point of view. Third, the comparison should be made only for the applicable range of Froude numbers. For example, vehicles with lower Froude numbers are not directly comparable to those with higher value because it is not possible to simultaneously maximize V and L. Fourth, although speed and Froude number are two very useful parameters, other parameters, such as endurance, may be more meaningful in some cases. Fifth, any judgements about vehicle substitutions to improve energy efficiency on the basis of these charts should be carefully drawn. Most of these vehicles cannot be substituted on a one-to-one basis. Mission requirements must be carefully considered as well.

Certain insights result from Figures V-3 to V-6:

* The relative place of individual vehicles remains largely unchanged, irrespective of the relationships considered. For example, HH-3F always appears superior to HH-52 although the margin of superiority changes from Figure V-3 to V-4 and from Figure V-5 to V-6.

FIGURE V-3

TRANSPORT EFFICIENCY - MAXIMUM SPEED
FOR SOME COAST GUARD VEHICLES

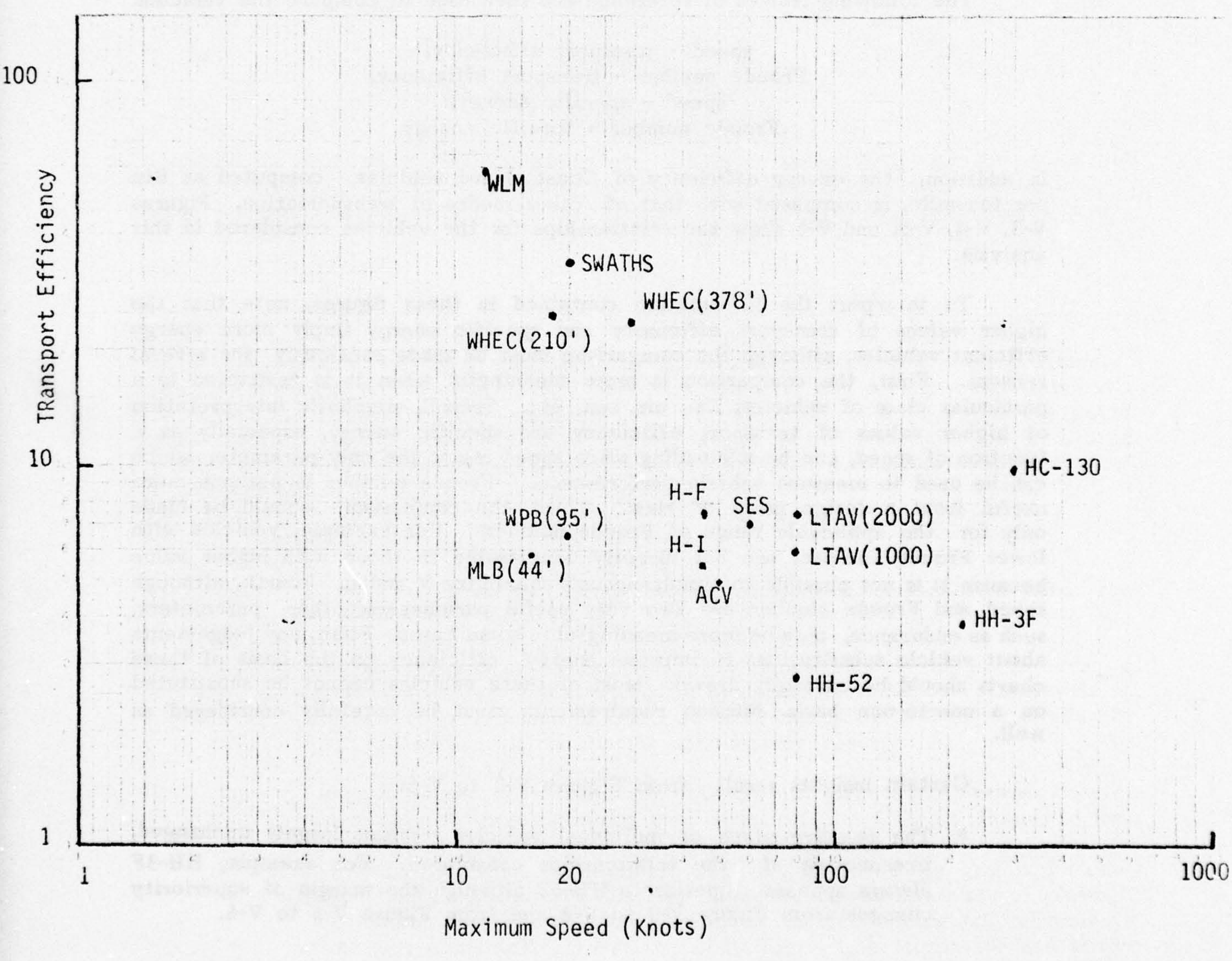


FIGURE V-4

TRANSPORT EFFICIENCY - FROUDE NUMBER
FOR SOME COAST GUARD VEHICLES

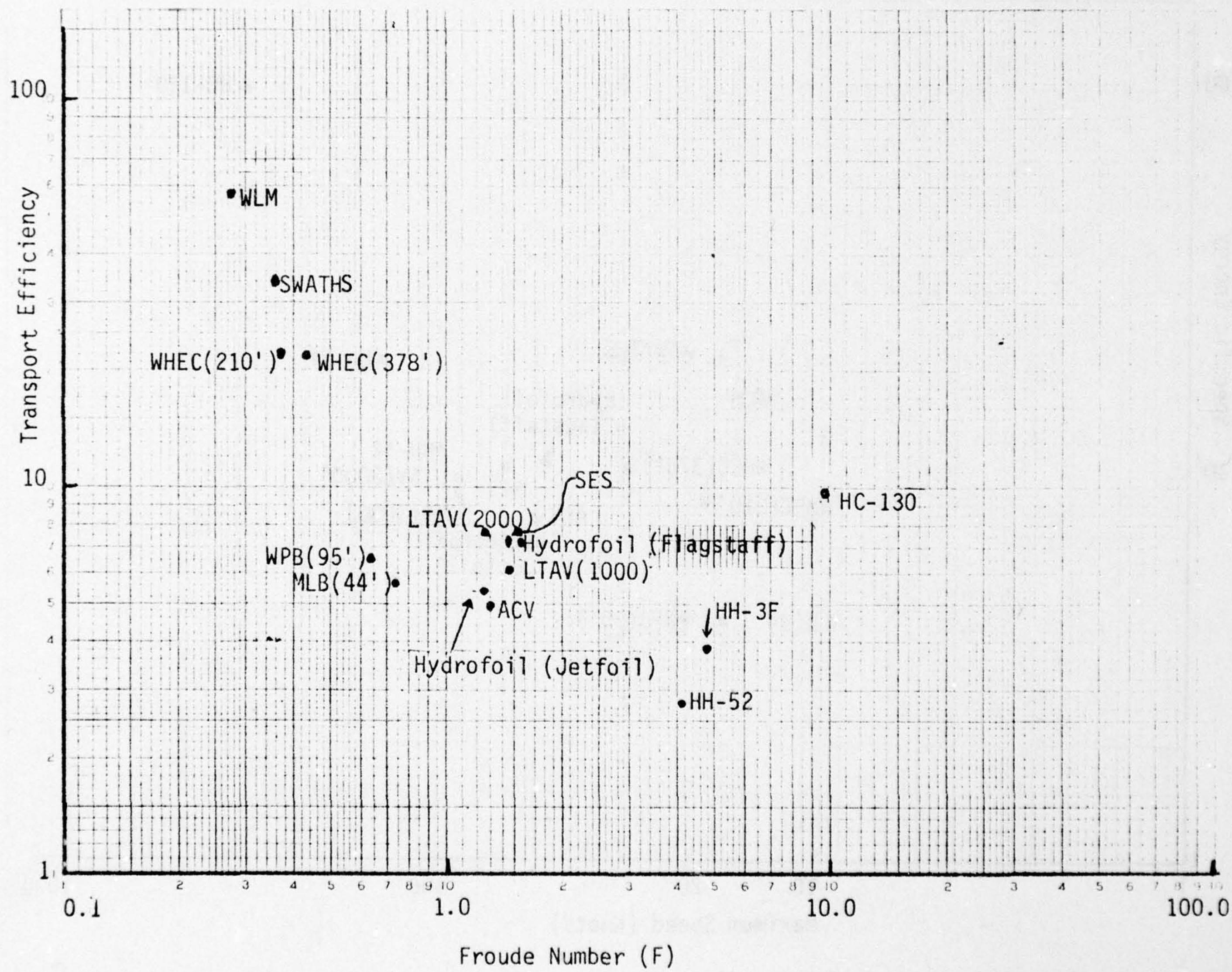


FIGURE V-5

SPECIFIC ENERGY - MAXIMUM SPEED
FOR SOME COAST GUARD VEHICLES

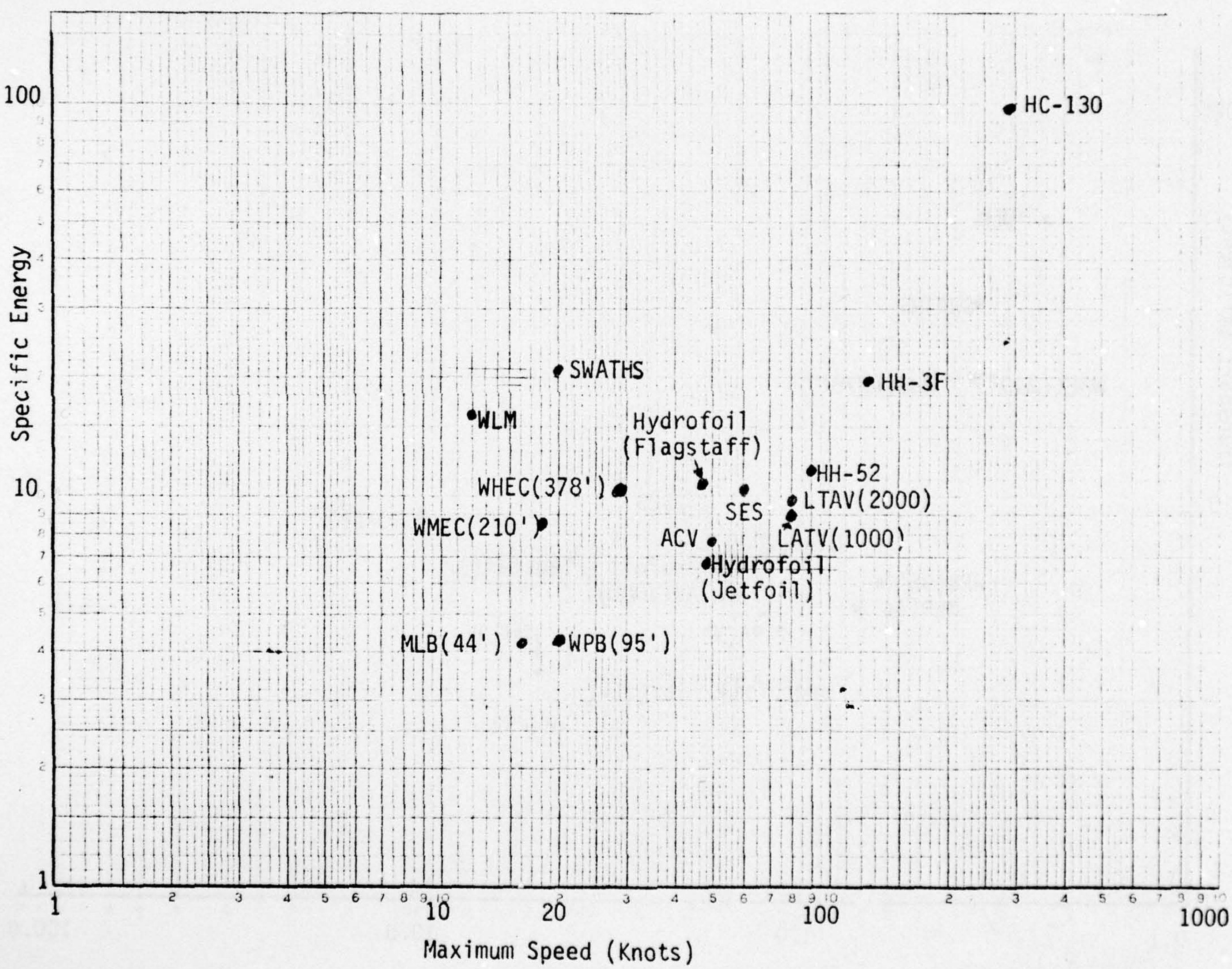
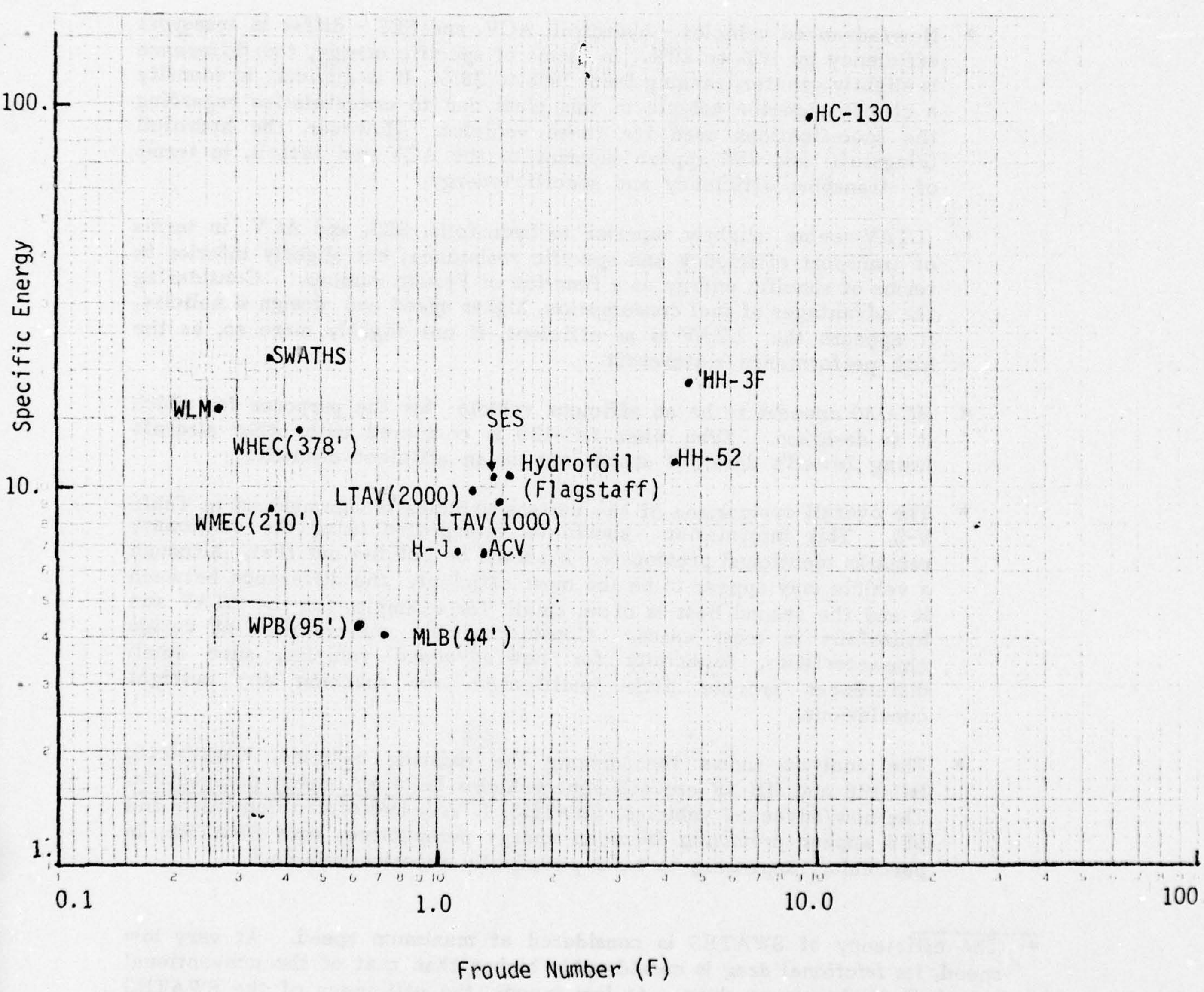


FIGURE V-6

SPECIFIC ENERGY - FROUDE NUMBER
FOR SOME COAST GUARD VEHICLES



* The transport efficiency of the coastal tender (WLM) is higher than any other vehicle, although this may be the result of sacrificing speed and performance. It should also be noted that WLM cannot possibly match the performance of some other vehicles, in terms of speed and survivability. Also, it should be noted that the other types of tender (e.g., WLI-100A and WLR-65) have a transport efficiency much lower than that of the WLM-175 considered here. Thus, the superiority of WLM cannot be generalized.

* SWATHS, at least in terms of the characteristics assumed here, appears to be superior to the existing cutters WHEC-378 and WMEC-210, both in terms of transport efficiency and specific energy.

* New/advanced vehicles - hydrofoil, ACV, and SES - differ in transport efficiency by 10% to 20%. In terms of specific energy, the difference is slightly greater, ranging from 10% to 30%. It is difficult to identify a clearly superior vehicle in this class due to uncertainties regarding the specifications used for these vehicles. However, the hydrofoil (Flagstaff) and SES appear superior to the ACV and Jetfoil, in terms of transport efficiency and specific energy.

* LTAV seems slightly superior to hydrofoils, SES, and ACV in terms of transport efficiency and specific resistance, but slightly inferior in terms of specific energy as a function of Froude number. Considering the advantages of fuel consumption, higher speed and design simplicity, it appears the LTAV is as efficient, if not slightly more so, as the high performance watercraft.

* HC-130 appears to be an efficient vehicle for the purposes for which it is designed. Even when HC-130 is compared with other aircraft (using Jewell's data), it stands out as an efficient aircraft.

* The overall comparison of the various vehicles is summarized in Table V-2. This information should be interpreted using the cautionary remarks mentioned previously. It should be pointed out that, although a vehicle may appear to be the most efficient, the difference between it and the second best is often small; for example, for the LTAV and hydrofoils in most cases. Considering the uncertainties of design characteristics, especially for new/advanced vehicles, such small differences provide little justification for reaching any outright conclusions.

* The analysis shows that among the existing vehicles, WMEC-210, HC-130 and HH-3F are efficient vehicles from an energy perspective. The new/advanced vehicles, SWATHS, LTAV, hydrofoil (Flagstaff), and SES appear promising from an energy perspective, with SWATHS, in particular, appearing to be a potentially superior vehicle.*

---

* The efficiency of SWATHS is considered at maximum speed. At very low speed, its frictional drag is considerably higher than that of the conventional monohull displacement ships. At low speeds, the efficiency of the SWATHS vehicle will appear somewhat lower than delineated here. For a good discussion of the SWATHS concept, see: "The SWATHS Concept: Designing Superior Operability into a Surface Displacement Ship", by Robert Lamb, Naval Research and Development Center, December, 1975; and "SWATH -A Status Report", by Seth Hawkins and T. Sarchin, February, 1974.

TABLE V-2

VEHICLE COMPARISON

	Transport Efficiency*	Specific Energy*
Maximum Speed		
≤ 20 knots	WLM, SWATHS, WMEC-210, WHEC-378, WPB, MLB	SWATHS, WLM, WHEC-378, WMEC-210, WPB, MLB
20-50 knots	Flagstaff, SES, Jetfoil, ACV	Flagstaff, SES, ACV, Jetfoil
50-100 knots	LTAV(2000), LTAV(1000), HH-52	HH-52, LTAV(2000), LTAV(1000)
>100 knots	HC-130, HH-3F	HC-130, HH-3F
Froude Number		
≤	WLM, SWATHS, WMEC-210, WHEC-378, WPB, MLB	SWATHS, WLM, WHEC-378, WMEC-210, WPB, MLB
1-4	LTAV(2000), SES, Flagstaff, LTAV(1000), Jetfoil, ACV	Flagstaff, SES, LTAV(2000), LTAV(1000), Jetfoil, ACV
4-10	HC-130, HH-3F, HH-52	HC-130, HH-3F, HH-52

* The vehicles are shown in decreasing order of superiority.

2. Comparison of Some Coast Guard Vehicles with Other Modes of Transportation

It is useful to compare the Coast Guard vehicles considered in the previous discussion with other modes of transportation. This comparison is shown in Table V-3.

The parameter chosen for comparison is energy intensity expressed as Btu per ton-mile. This parameter is often used in the literature on transportation where it is usually defined as Btu expended to transport goods/passengers weighing one ton over one mile. Speed is not explicitly considered in such estimates.

On the other hand, we derive the Btu per ton-mile on the basis of specific resistance of different vehicles. This parameter (P/WV), in essence, specifies energy intensity as a dimensionless quantity by considering P in ft-lb/sec, W in lbs, and V in ft/sec. The Btu per ton-mile figures can be derived by considering P in Btu/sec, W in tons, and V in miles per second. Note that W and V are maximum weight and speed while P is continuously available shaft horse-power to transport the momentum WV. The Btu per ton-mile figures given here signify the energy required to transport goods/passengers weighing one ton over one mile when the vehicle is fully loaded and operating at the maximum designed speed. For this reason, the figures cited here will differ from those in the literature where the figures are usually derived from data on tons of commodity moved and assumptions about average miles for a typical haul. Since the Coast Guard does not compile such data for its vehicles, the measure developed as above is more suitable.

Table V-3 reveals that the Coast Guard vehicles are as efficient or more efficient (e.g., HC-130) than their counterparts in the civilian sector, on a Btu per ton-mile basis. The cutters in general have lower values of Btu per ton-mile while the new/advanced vehicles, including LTAV, have energy intensity lower than some civilian vehicles, including the automobile, with characteristics specified in Table V-3. (The energy intensity of the automobile, shown in Table V-3, is probably on the high side).

C. Level 2 Analysis: Energy Analysis of Alternate Fuels

Chapter IV included the discussion on the importance of two types of alternative fuels for future use by Coast Guard vehicles. These alternative fuels are derived from coal and oil shale. In this section, we compare the two alternative fuels with the conventional (natural) crude oil, from an energy perspective. The analysis utilizes the concept of energy accounting, sometimes labeled as net energy analysis. This concept is designed to identify the amount of energy used in the process of extracting a primary resource, such as coal and oil shale, and transforming and delivering it to the point of final use.

The energy supply system considered for analysis is shown in Figure V-7. This somewhat idealized system depicts the energy flow from the source (e.g., crude oil well, coal mine) to the end use (i.e., the vehicle). The flow of energy from the source to the end use involves various stages and processes; for example, extraction, refining, processing, transportation, and distribution. Each system component converts,

TABLE V-3

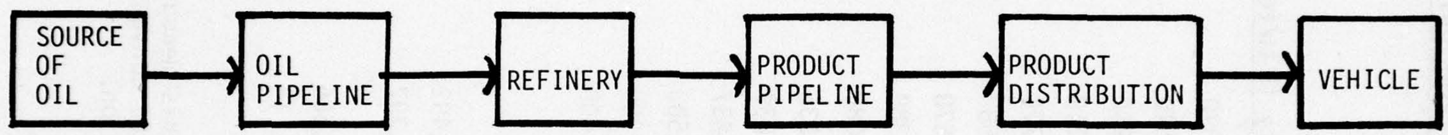
COMPARISON OF CG VEHICLES WITH OTHER MODES OF TRANSPORTATION

CG Vehicles	Energy Intensity (Btu/ton-mile)*
HC-130	1,370
HH-3F	3,540
HH-52A	4,960
LTAV (1000)	2,310
LTAV (2000)	1,770
WHEC-378	580
WMEC-210	570
MLB-44	2,380
WPB-95	2,080
WLM	235
ACV	2,639
SES	1,837
Hydrofoil: Jetfoil	2,500
Hydrofoil: Flagstaff	1,900
SWATH Ship	400
Other Modes of Transportation	
Boeing 727	3,492
DC-10	3,797
Auto: 5500 lbs., 320 hp, 100 mph max. speed	2,866
Large Oil Tanker	14

* See text of the report for an interpretation of this measure. It is not identical to the measure generally mentioned in the conventional literature on transportation, especially freight transportation.

FIGURE V-7

SYSTEM TO SUPPLY PETROLEUM PRODUCTS



transports, or distributes its energy input and in doing so, require ancillary energy inputs in the forms of electricity and fuels (diesel, coal, etc.). This ancillary energy input represents the energy content of the primary resources used to produce it in the first place. For example, electricity is one of the ancillary energy inputs in the refining of crude oil and, if electricity is produced from coal, the energy content of the amount of coal used to produce electricity is estimated and included in the analysis so that the conversion losses incurred in producing electricity are reflected in the total energy budget. The ancillary energy input to each component of the system also includes the indirect energy embodied in materials used by the system component, to the extent possible.

Table V-4 summarizes the ancillary energy requirements as well as the energy efficiency of each system component, (Ref. 7). The estimates of ancillary energy requirements are derived by considering the accounting procedure delineated above. The estimates are used to compute the total energy consumed by the supply system to produce and deliver 1 million Btu of energy to the vehicle. Figures V-8, V-9, and V-10 summarize the analysis for the three cases when the refined products are derived from conventional crude (Figure V-8), oil shale (Figure V-9), and coal using the H-Coal liquification process (Figure V-10). Identical definitions are used for the system components common to the three supply systems (e.g., product pipeline) so the comparison remains consistent. Further, for the coal-based system, it is assumed that coal conversion takes place near the refining complex, thus requiring additional energy for transportation. In the case of oil shale, however, synthetic crude is produced at the oil-shale mine, thus requiring a crude oil pipeline to the refining complex. The number in each box denotes its energy efficiency. Total energy consumption is then the sum of system losses and ancillary energy requirements. Both of these quantities are estimated to supply 1 million Btu of delivered energy to the vehicle. System losses are estimated using the energy efficiencies of individual system components.

The results indicate that to supply 1 million Btu of energy to the vehicle, the conventional crude oil system will consume .267 million Btu, the oil-shale based supply system will consume .687 million Btu, and the coal-based synthetic fuel supply system will consume .745 - .892 million Btu, depending on the quality of coal used. Thus, the existing system based on the conventional source of oil supply is considerably more attractive in terms of total energy consumption, followed by oil shale and coal derived synthetic fuels. The two synthetic fuel systems have lower net energy primarily because of the energy requirements of the conversion process - the retorting and upgrading step in Figure V-7 and the coal-to-liquid conversion step in Figure V-8. As the technology of conversion improves, the gap between conventional crude and synthetic fuels could become smaller. Further, as the easily recoverable resources of conventional crude oil are depleted, the quantity of ancillary energy required to produce it will increase, which will also could narrow the gap.

The difference between oil-shale-based and coal-based systems is 8% to 30%. This difference is sensitive to the definition of system components in Figures V-7 and V-8. For example, if one assumes that coal conversion takes place near the mine producing bituminous coal and is also refined near the mine to supply the near-by markets, the energy consumption of the coal-based supply system becomes .699. The advantage of the oil-shale-based supply system in such a case almost disappears.

TABLE V-4

ENERGY REQUIREMENTS FOR SYSTEM COMPONENTS

Component	Energy Efficiency	Ancillary Energy ($BTU/10^6$ BTU Output)
Coal Mine		
Surface	1.0	$2.8 \times 10^5/HV$ [a]
Underground	1.0	$3.4 \times 10^5/HV$
Coal Transport		
Unit Train	1.0	$(2000/HV) \times L$ [b]
Barge	1.0	$(300/HV) \times L$
Coal Conversion		
Syncrude (Bituminous Coal)	0.68	2.7×10^4
Syncrude (Subbituminous Coal)	0.63	2.7×10^4
Crude Oil Pipeline	1.0	$48 \times L$
Product Pipeline	1.0	$15 \times L$
Product Distinction	1.0	0.5×10^4
Refinery	0.96	6.2×10^4

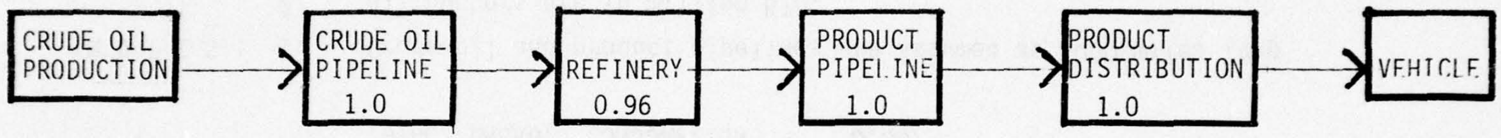
NOTES:

a. HV = Heating value of coal in million BTU/ton.

b. L = Transport distance in miles.

FIGURE V-8

ENERGY CONSUMPTION BY CONVENTIONAL CRUDE OIL SUPPLY SYSTEM



Ancillary Energy	.08	.048	.028	.015	.056

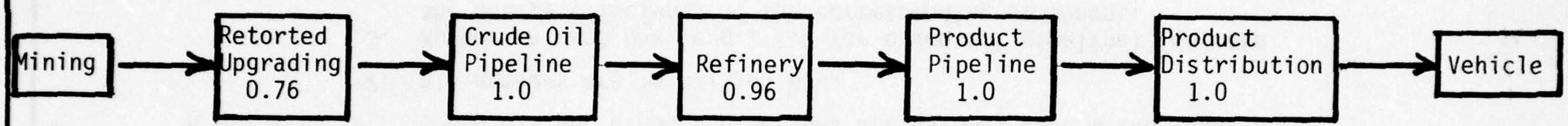
TOTAL ANCILLARY ENERGY	0.227
TOTAL SYSTEM LOSSES	.04
TOTAL ENERGY CONSUMPTION	0.267

NOTE :

1. Crude oil and product pipelines are assumed 1000 miles long
2. All numbers are in million BTU.
3. Number in each box (e.g., 1.0 for crude oil pipeline) indicate the energy efficiency of the corresponding component.

FIGURE V-9

ENERGY CONSUMPTION BY OIL-SHALE-BASED SYNTHETIC CRUDE OIL SUPPLY SYSTEM



Ancillary Energy					
.04	.13	.048	.028	.015	.056

TOTAL ANCILLARY ENERGY	0.317
TOTAL SYSTEM LOSSES	0.37
TOTAL ENERGY CONSUMPTION	0.687

NOTES:
1. Crude oil and product pipelines are assumed as 1000 miles long
2. All numbers are in million BTU.
3. Number in each box represents the energy efficiency of the corresponding component.

FIGURE V-10

ENERGY CONSUMPTION BY COAL-BASED SYNTHETIC CRUDE OIL SUPPLY SYSTEM

	Coal Mine	Coal Transport 1.0	Coal Conversion .68-.63	Crude Oil Pipeline -	Refinery 0.96	Product Pipeline 1.0	Product Distribution 1.0	Vehicle
Ancillary Energy								
·Bituminous Coal:24x10^6 Btu/Ton	.022	.031	.029	-	.062	.015	.056	
·Sub-bituminous Coal:16x10^6 Btu/Ton	.029	.051						

Total Ancillary Energy	.215 - .242	
Total System Losses	.53 - .65	
Total Energy Consumption	.745 - .892	

Notes:
1. Product pipeline assumed 1000 miles long.
2. Heating values of coal are selected to cover the extreme range of values.
3. Coal transport by unit train is assumed.
4. Number in each box represent the energy efficiency of the corresponding component.

The analysis points out the relative merits of the three systems based on an energy accounting perspective. It is important that the results of this analysis be viewed along with other dimensions, (e.g., the economics of production), before one can make judgements regarding the superiority of a particular system, (e.g., oil-shale over coal-based systems). This is particularly so because controversy exists on the merits of energy accounting, net energy analysis types of approaches vis-a-vis the economic analysis. The arguments in favor of net energy analysis, however, are likely to increase in the future (e.g., see Wall Street Journal, May 3, 1979, p.1).

D. Level 3 Analysis: Aggregate Analysis of Relevant Vehicles for Performing Selected Coast Guard Missions

1. Scope and Structure of the Analysis*

The Level 3 Analysis involves the evaluation of relevant vehicles to perform selected Coast Guard missions. Two criteria for evaluation are considered: energy consumption and response time. The evaluation is arrived at by constructing scenarios describing the situations in which Coast Guard responses are required. These scenarios describe the characteristics of the missions to be performed and the tactics to be employed for the Coast Guard responses. Each scenario has three major components: mission performed, vehicles deployed, and tactics employed.

Since the universe of likely scenarios is quite large, it was necessary to restrict our analysis to a few representative but significant missions and only to the most relevant vehicles. The analysis was bounded by considering the results of the mission and relevance analyses (Chapter III), and technology forecasts (Chapter IV).

We developed scenarios for each of the following missions involving incident responses:

- SAR (rescue only)
- SAR (search)
- ELT (fisheries)
- ELT (smuggling)
- MEP (oil spill)

Further, one patrol (surveillance) mission was also included.**

Relevant vehicles were chosen to perform each mission and tactics were specified to indicate how the vehicles are used to perform the mission. To use the results of the technology forecasts, we distinguished each scenario in terms of vehicles available in 1980, 1990, and 2000. The vehicles for 1980 scenarios were restricted to those in the current fleet. For 1990 and 2000, we used the results of technology forecasts so as to include those which could result in lowering the fuel consumption of the existing vehicles, the new/advanced vehicles, and non-vehicle technologies.

* For an alternate approach see Appendix F.

** PSS, ranked high in importance in Chapter II, is not included here since it is inherently low energy consuming (using small vehicles).

Once the mission characteristics (e.g., the nature of the incident requiring a response) and vehicles used are specified, the choice of tactics, specifying how vehicle(s) will be used to perform the mission is delineated. Various parameters can be used to specify the tactics (e.g., altitude and speed of an aircraft). Realizing that the energy consumption of a vehicle is significantly dependent upon the speed, tactics are specified principally in terms of speed profile of the vehicle(s) over the mission duration. The speed profile is specified in terms of three discrete values of speed - loiter, cruise, and dash. Although these terms are often used in the literature, their interpretation is not always clear. In our analysis, the interpretation is as follows: loiter - a low speed, necessary for hovering and close surveillance purposes; cruise - speed at which vehicle performance is "optimum", more or less the speed at which a vehicle is designed for continuous operation; dash-near maximum design speed of a vehicle. Our analysis thus considers only three discrete values of speed and does not reveal the trade-offs between speed, energy consumption, response time over all values of vehicle speed. However, the analysis does provide meaningful bounds since the speed profile covers the extremes of vehicle speed.

We have selected the parameters of Level 3 analysis to insure consistent comparison of various alternative vehicles and tactics in performing a given mission. Thus, we compare vehicles in different time frames to perform identical missions. We have also employed two criteria for vehicle evaluation: energy consumption because of its principal role in this study, and response time to include a measure of performance. Since the speed profile is used to specify tactics, response time seems to be an appropriate performance criteria for evaluation.

2. Approach

The energy and response time analysis is a parametric pairwise comparison of relevant vehicles, used according to specified tactics to perform the given mission. The approach consists of the following steps:

(a) A scenario describing three major components (situation, vehicle mix, speed profile) is developed for each mission delineated in the previous section.

(b) For each alternative way to perform the mission (i.e., a set of vehicles used according to specified tactics), energy consumption and response times are estimated. The energy consumption of an alternative is the sum of energy requirements of all vehicles used to perform the mission. The response time is the maximum time needed to complete the mission.

(c) Since energy consumption and response time are functions of distance traveled by various vehicles according to a certain speed profile, it is necessary to specify the distance between the incident and the initial location of the vehicles used in the mission. The number of such discrete possibilities is clearly quite large. To overcome this problem, we estimate energy consumption and response time as a function of normalized distances. The normalized distance is the ratio of distance between the incident and the locations of vehicles to be used at the time of the incident occurrence. For example, if the incident occurs at a distance DI away from vehicle VI and DB from vehicle V2, we analyze the situation in terms of the ratio DI/DB.

(d) We estimate energy consumption and response time of each alternative tactic and then perform a pairwise comparison of various alternatives for the same time period (e.g., 1980) as well as for different time periods (i.e., comparing best 1980 alternatives with best 1990 and 2000 alternatives), as indicated in Figures V-11 and V-12.

(e) The results of the comparative evaluation of the vehicles are given in the following forms:

(1) ranking the vehicles in terms of energy consumption and response time.

(2) numerical values for upper and lower bounds for energy consumption and response time ratios indicating the margin by which the best alternative is superior to other alternatives, for the range of normalized distance being considered.

The data on energy consumption of the vehicles used in this analysis are based on information from various sources and was checked for consistency. The data shown in Table V-1, at the indicated speeds, was used to estimate energy consumption for the two other values of vehicle speed, using appropriate scaling laws. The estimates used in the analysis are shown in Table V-5. The remarks made earlier about the adequacy and accuracy of the fuel consumption data in Table V-1 apply equally to the data in Table V-5.

The data for energy consumption in future years resulted from technology forecasts. The multipliers shown in Table V-6 were used to adjust the figures in Table V-5 in specifying energy consumption in years 1990 and 2000. The surveillance characteristics of the vehicles used in the analysis of patrol missions are shown in Table V-7. These were derived from previous studies done for the Coast Guard. (e.g., CNA studies on hydrofoils and LTAV).

A mathematical model was developed to conduct the comparative analysis of the alternatives. The model estimates the optimum alternative by searching for the alternative with minimum energy consumption and response time. The use of the model greatly simplifies and systematizes the computational aspects. Although the calculations for this analysis were done by hand, the model can be easily programmed on a computer. We believe the model is useful for more sophisticated analysis in the future, and some areas for such analysis are indicated later. In this respect, we believe that the Level 3 analysis has produced not only insights into the comparative evaluation of vehicles but, perhaps more importantly, techniques (models) which can be used and extended for future use by the Coast Guard.

3. Results

In this section, we present results of the model application for evaluating the vehicles when used to perform missions depicted in alternate scenarios. The results are presented for the missions mentioned in section D1, for 1980, 1990, and 2000. The analysis of vehicles involves comparisons (a) among vehicles for each of these three time points and (b) among best alternatives at different time points. The results are described in a common format which includes:

FIGURE V-11

LEVEL 3 ANALYSIS APPROACH

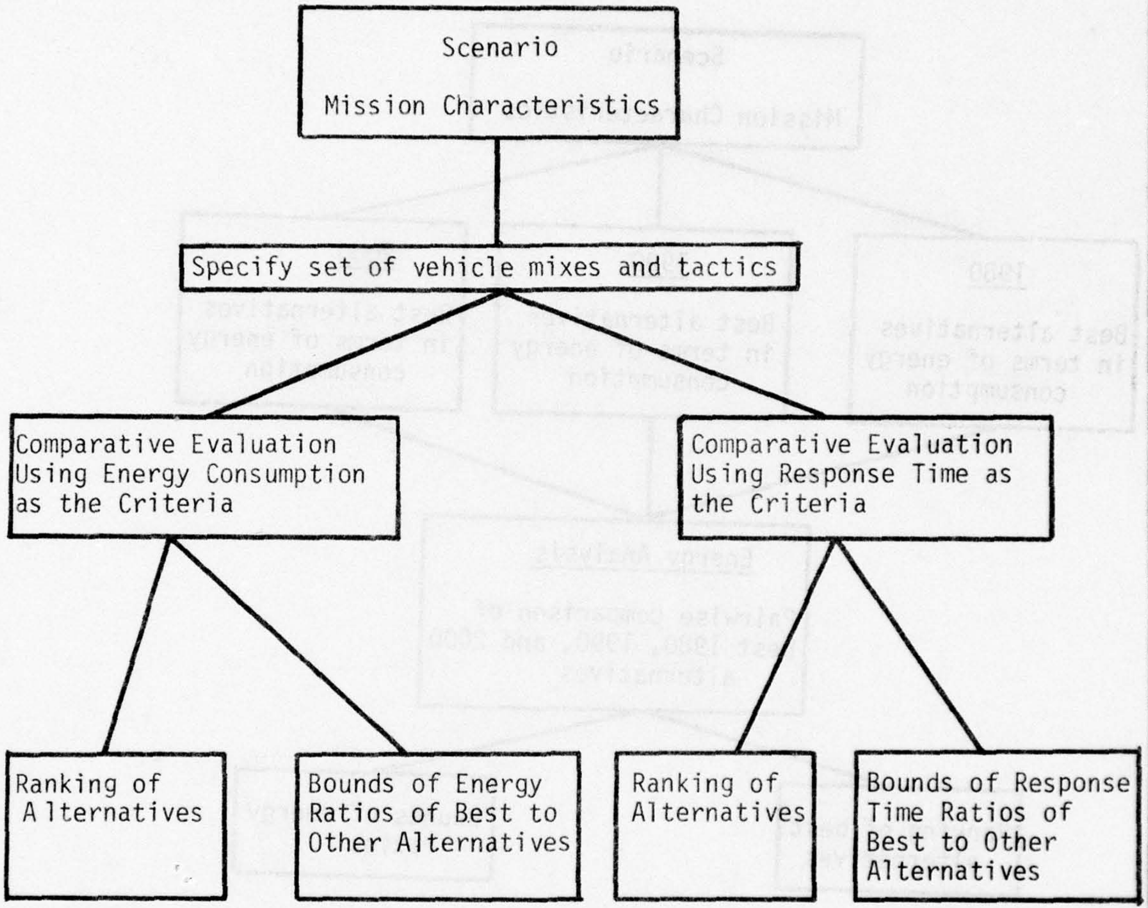
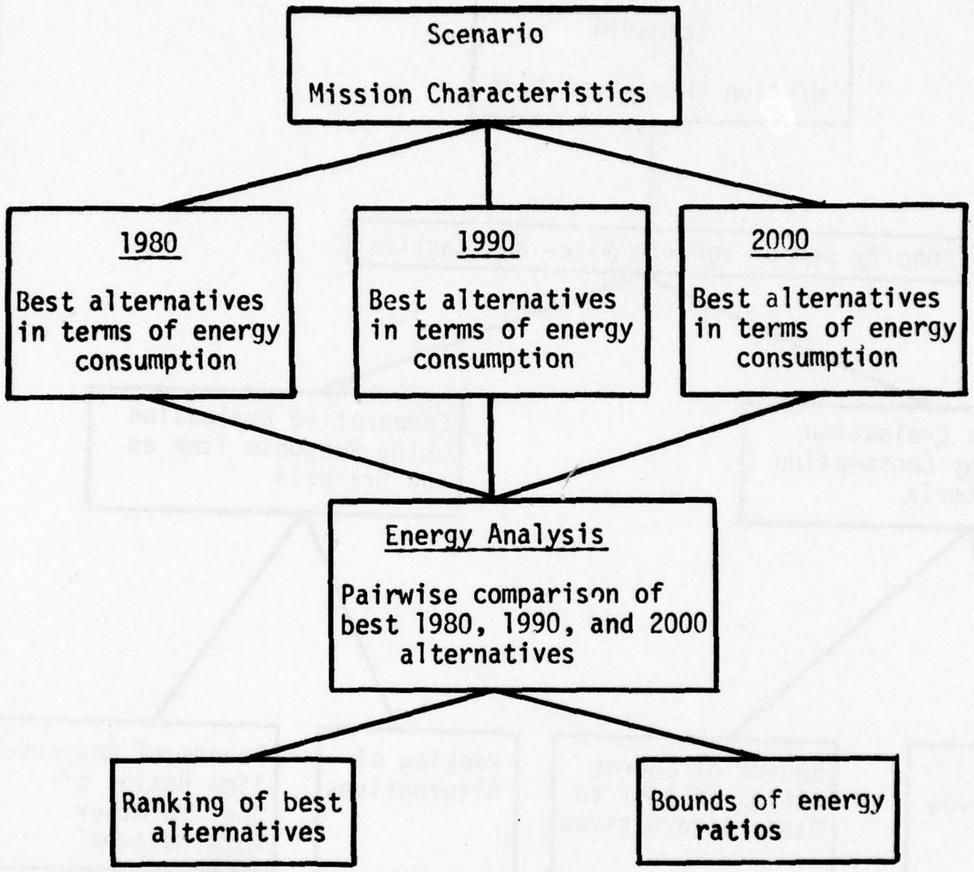


FIGURE V-12

LEVEL 3 ANALYSIS APPROACH



NOTE: A similar flow chart applies to response time analysis.

TABLE V-5

ESTIMATE OF FUEL CONSUMPTION
(at speed, in knots, indicated in parentheses)

Vehicle	Gallons/Hour		
HC-130	660 (290)[b]	765 (210)[a]	660 (180)[a]
MRS	285 (370)[b]	285 (230)[a]	210 (180)[a]
HH-52	90 (90)	70 (70)[c]	60 (60)[c]
HH-3F	186 (125)	150 (100)[c]	120 (80)[c]
Cessna, Model 320	5 (100)	6 (120)	8 (200)
WHEC-378	2,514 (29)	344 (19)	96.6 (low)
WMEC-210	315 (18)	108 (14)	20 (low)
WPB-95	125 (20)	9 (9)	5 (5)
WLR	60 (11)[c]	12 (6)[c]	3 (2)[c]
MLB	42 (16)[c]	10 (11)[c]	5 (5)[c]
ACV-1[d]	350 (50)	210 (40)	35 (5)
ACV-2[d]	715 (50)	428 (40)	71 (5)
SES-1[d]	525 (60)	315 (48)	52 (5)
SES-2[d]	875 (60)	525 (48)	88 (5)
Hydrofoils			
--Patrol hydrofoil missile	840 (48)	60 (12)	30 (5)
--Jetfoil	609 (46)	45 (12)	18 (5)
--Flagstaff	262 (48)	40 (10)	32 (5)
SWATHS[d]	770 (20)	270 (12)	40 (5)
LTAV-1000[e]	93 (80)	62 (70)	23 (50)
LTAV-2000[e]	144 (80)	88 (70)	30 (50)

NOTES:

a. At low altitude

b. At high altitude

c. Should be considered as very approximate estimates, since altitude and/or environmental conditions are unaccounted for.

d. These are hypothetical ships with physical characteristics as follows: ACV-1, 75 tons, 39'; ACV-2, 170 tons, 133'; SES-1, 100 tons, 105'; SES-2, 250 tons, 150'; SWATHS, 3000 tons, 275'. The estimates of fuel consumption were derived through literature search and adopting reasonable estimates.

e. LTAV-1000 and LATV-2000 are those considered in the CNA study for the CG on Lighter-Than-Air Vehicles, 1000 and 2000 miles range, 80-100 knot speed.

TABLE V-6

MULTIPLIERS FOR ESTIMATING FUTURE ENERGY CONSUMPTION

Vehicle	1990	2005
Fixed wing aircraft	0.94	0.94
Rotary wing aircraft	0.96	0.96
Cutters/Boats	0.96	0.92
New Vehicles SES, ACV, HYD SWATH Ship, etc.	0.83	0.60

TABLE V-7

SURVEILLANCE CHARACTERISTICS

Vehicle	Detection Perpendicular to Path (Miles)	Sweepwidth (Miles) Medium Targets	Sweepwidth (Miles) Small Targets
Fixed wing aircraft	25	50	25
Rotary wing aircraft	20	40	20
Airships	30	60	38
Hydrofoil/ Flagstaff	18	36	18
Cutters	18	36	18

* written description of the scenarios,

* specification of vehicle alternatives,

* specification of how the vehicles are used, primarily the relative location and speed profile,

* ranking in terms of energy consumption and response time; ranking is dependent upon the range of normalized distances between the vehicle location and the incident,

* numerical values of energy and response time ratios. As mentioned earlier, these ratios indicate the margin of superiority of the best alternative over other alternatives for the applicable range of normalized distances,

* summary of the principal findings.

The terminology is fully explained in the description of the first scenario only, SAR-rescue (Table V-8), and later where needed. The 1980 analyses are presented first, followed by analyses for 1990 and 2000, and the comparative analysis of best alternatives of 1980, 1990, and 2000.

4. Comparative Analysis of Six Scenarios for 1980

The description and results are presented in Tables V-8 through V-13.

TABLE V-8

Comparative Analysis of Scenario 1

Mission: SAR (rescue only)
Time: 1980

A. Description

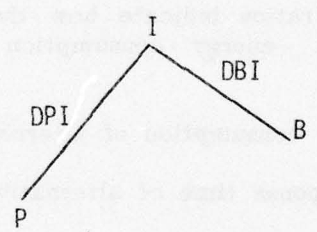
A 40' sailboat is caught in mild storm conditions in the Great Lakes. It has taken on water but is staying afloat. There are six people on board with one injured. Weather conditions are deemed suitable for helicopters.

In this vignette we focus only on the rescue phase of a search and rescue operation. Search is handled separately in Scenario 2. This division is appropriate for purposes of detailed energy analysis, due to the different requirements of the two kinds of tasks.

The alternative responses to this incident may involve a surface patrol, a vehicle sent from a Coast Guard base, or both. It is necessary to remove the people from the craft and to bring the craft to base.

B. Alternatives and Tactics

The alternatives are described by developing terminology to compact the description. The terminology is developed as follows.



I = incident location	d = dash speed
P = patrol location	c = cruise speed
B = base location	l = loiter speed

DPI = Distance between patrol and incident locations.
DBI = Distance between base and incident locations.
R = $\frac{DPI}{DBI}$, represents the normalized distance.

The alternatives can be described in terms of vehicles used and tactics employed to perform the mission. We identify four alternatives to perform this mission. Specifically, alternative A1 involves HH-3F (on WMEC-210) traveling at dash speed from patrol to the incident, and at cruise speed from the incident to the base. At the same time, WMEC-210 travels at cruise speed from patrol to the incident, and at cruise speed from the incident to the base. The alternative A1 can be symbolically described as follows:

A1

HH-3F: PI/d, IB/c
WMEC-210: PI/c, IB/c

Here the first two letters identify the distance and the letter following "/" denotes the speed. Thus, PI/d means covering distance PI at speed d.

Similarly, other alternatives can be described as follows:

A2

HH-3F: BI/d, IB/c
WPB-95: PI/c, IB/c

A3

HH-3F: BI/d, IB/c
WPB-95: BI/d, IB/c

A4

HH-52: BI/d, IB/c
MLB: BI/c, IB/c

C. Rankings and Ratios

The rankings and ratios indicate how the various alternatives compare in terms of energy consumption and response time. Symbolically:

$E(A_i)$ = Energy consumption of alternative A_i

$T(A_i)$ = Response time of alternative A_i

Then:

$$RE(A_i, A_j) = \frac{E(A_i)}{E(A_j)}$$

$$RT(A_i, A_j) = \frac{T(A_i)}{T(A_j)}$$

Since $RE(A_i, A_j)$ and $RT(A_i, A_j)$ are functions of the normalized distance $R = \frac{DPI}{DBI}$, we have to assume bounds for R and then determine the alternatives with minimum and maximum energy consumption and response times, within the specified bounds of R.

The energy and response times are then estimated, as indicated in the previous section, for the assumed bounds of R. The information on R, ranking and ratios, provided below, should be interpreted as follows:

- Bounds of R - range of R within which the ranking applies. Thus R = 0-5 means that the value of R lies between 0 and 5, (i.e., $0 \leq R \leq 5$).

- Ranking is shown in decreasing order of superiority. A ranking A4, A2, A3, A1 means A4 is superior to A2, A3, A1; A2 is superior to A3, A1; and, so on.

- Energy and response time ratio correspond to the range of R shown in the first column. As indicated earlier, the ratio is a quantitative measure of the superiority of the best alternative. The bounds for the ratios indicate the margin of superiority. For example, the ratio RE (A4,A2): 0.76-0.95 means that energy consumption of A4 can be as low as 76% of the energy consumed by A2 and as high as 95% of the energy consumed by A2. Response time ratios should be interpreted in a similar manner.

Ranking and Ratio in Terms of Energy Consumption

R	Ranking	RE	
0-1	A4, A2, A3, A1	(A4, A2):	0.76-0.95
		(A4, A3):	0.76
		(A4, A1):	0.21-0.42
1-5	A4, A3, A2, A1	(A4, A3):	0.76
		(A4, A2):	0.43-0.64
		(A4, A1):	0.07-0.14

Ranking and Ratio in Terms of Response Time

R	Ranking	RT	
0-0.64	A1, A2, A4, A3	(A1, A2):	0.76
		(A1, A4):	0.39-0.64
		(A1, A3):	0.32-0.52
0.64-1	A1, A4, A2, A3	(A1, A4):	0.64-0.78
		(A1, A2):	0.64
		(A1, A3):	0.52-0.64
1-1.56	A1, A4, A3, A2	(A1, A4):	0.78-1
		(A1, A3):	0.64-0.82
		(A1, A2):	0.64
1.56-2.13	A4, A1, A3, A2	(A4, A1):	0.82-1
		(A4, A3):	0.82
		(A4, A2):	0.52-0.64
2.13-5	A4, A3, A1, A2	(A4, A2):	0.82
		(A4, A1):	0.43-0.82
		(A4, A2):	0.27-0.52

D. Findings

1. In terms of energy consumption, A4 is the best alternative for the entire region R = 0-5, while A1 is the worst alternative.

2. In terms of response time, A1 is the best alternative, when R = 0-1.56. A4 is the best alternative when R = 1.56-5.

3. Thus, when R = 1.56-5, A4 is the best alternative in terms of both the energy consumption and response time.

TABLE V-9

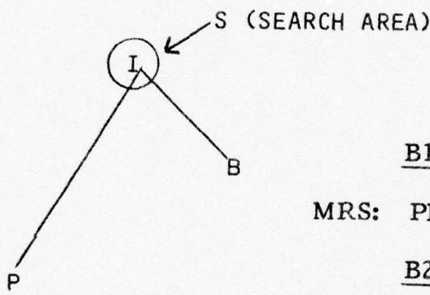
Comparative Analysis of Scenario 2

Mission: SAR (search)
Time: 1980

A. Description

Here we assume the same type of situation as in the SAR rescue vignette, but now focus on the search. Search operations may use aircraft or surface vehicles and these may respond from a patrol stance or be dispatched from a base. This analysis includes aircraft only because of their greater search range and higher speeds as compared to surface vehicles. Energy consumption is a function of time of search, plus distance to search area.

B. Alternatives and Tactics



$$R = \frac{DPI}{DBI}$$

We assume $0 \leq R \leq 5$.

B1

MRS: PI/d, S/1

B2

HH-3F: BI/d, S/1, IB/c

B3

Cessna: PI/d, S/1

B4

HH-130: PI/d, S/1

The light general aviation aircraft (e.g., Cessna type) was included in the analysis of 1980 current vehicles although the Coast Guard does not have it in the current fleet.

C. Rankings and Ratios

Ranking and Ratio in Terms of Energy Consumption

R	Ranking	RE
0-5	B3, B1, B2, B4	(B3, B1): 0.04-0.05 (B3, B2): 0.03 (B3, B4): 0.02

Ranking and Ratio in Terms of Response Time

R	Ranking	RT
0-1.8	B1, B4, B3, B2	(B1, B4): 0.79-1.0
		(B1, B3): 0.57-0.76
		(B1, B2): 0.33-0.46
1.8-5	B4, B1, B3, B2	(B4, B1): 0.96-1.0
		(B4, B3): 0.73
		(B4, B2): 0.44-0.45

D. Findings

1. In terms of energy consumption, B3 is the best alternative.
2. In terms of response time, B1 is best when R = 0-1.8, while B4 is best when R = 1.8-5.

TABLE V-10

Comparative Analysis of Scenario 3

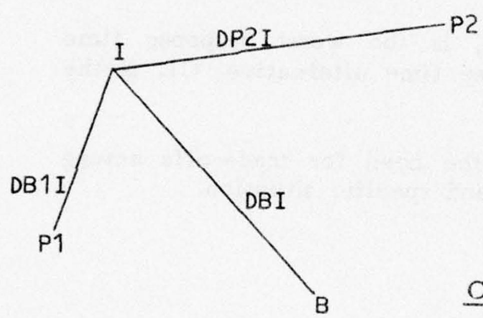
Mission: ELT (fisheries)
Time: 1980

A. Description

A soviet trawler is sighted in the North Atlantic, within the 200 mile fish conservation zone. An attempt is made to establish radio contact, but does not succeed. Closer surveillance indicates that the trawler is fishing illegally.

The various response alternatives may involve aerial patrol vehicles, surface patrol vehicles, or vehicles dispatched from base. An important aspect of this operation is the need for establishing and maintaining "hot pursuit" in the event the trawler tries to escape. Fixed wing aircraft are good only for short times before needing refueling, and therefore must be relieved by a vehicle with more endurance and/or capability of performing board and inspect operations (such as a helicopter).

B. Alternatives and Tactics



$$R1 = \frac{DP1I}{DBI}$$

$$R2 = \frac{DP2I}{DBI}$$

We assume: $0 \leq R1 \leq 5$
$0 \leq R2 \leq 5$

C1

MRS: P2I/d, I/1
HH-3F: P1I/d, IP1/c
WHEC-378: P1I/c, IB/c
(MRS loiters at I until the arrival of HH-3F).

C2

As C1, with Cessna-type instead of MRS

C3

As C1, with MRS from B instead of P2.

C4

As C3, with Cessna-type instead of MRS.

C. Rankings and Ratios

Ranking and Ratio in Terms of Energy Consumption

R1	R2	Ranking	RE	
0-5	0-5	C4, C3, C2, C1	(C4, C3):	0.5-0.69
			(C4, C2):	0.08-0.21
			(C4, C1):	0.07-0.21

Ranking and Ratio in Terms of Response Time

R1	R2	Ranking	RT	
0-5	0-5	C1, C2, C3, C4	(C1, C2):	0.89-1.0
			(C1, C3):	0.46-0.6
			(C1, C4):	0.46-0.59

D. Findings

1. In terms of energy consumption, C4 is the best alternative.

2. In terms of response time, C1 is the best alternative.

3. The best energy alternative, C4, is the worst response time alternative, while the best response time alternative, C1, is the worst energy alternative.

4. These "conflicting" results show the need for trade-offs among desired criteria for each mission and specific situation.

TABLE V-11

Comparative Analysis of Scenario 4

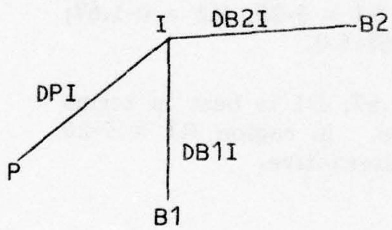
Mission: ELT (smuggling)
Time: 1980

A. Description

A 100' privately owned yacht is observed heading north along the southern California coast, about 25 miles offshore. Surveillance via routine aerial patrol shows that the craft matches a smuggler's "behavior profile". The yacht is traveling under sail.

This vignette involves two phases of response. First, the Coast Guard tightens surveillance and "tracks" the vessel, waiting for an attempted landing. The rationale behind this is the alarm should not be sounded until the unloading of contraband, etc., is in progress in order to apprehend as many involved persons as possible. Accordingly, there is some means required for this tracking operation, as indicated in the diagram by a line from a base (to the south), B2, to the incident. This may involve surface or airborne vehicles, or both. The second phase is the closing in and arrest, which may use nearby patrol vehicles or vehicles dispatched from a base in the vicinity.

B. Alternatives and Tactics



$$R1 = \frac{DB1I}{DB2I}$$

$$R2 = \frac{DPI}{DB2I}$$

We assume: $5 \leq R1 \leq 20$,
$0 \leq R2 \leq 5$

D1

WPB-95: B1I/c, IB2/c, B2B1/c
HH-3F: PI/d, IP/c
(HH-3F starts after WPB-95 arrives at I)

D2

WPB-95: B1I/c, IB1/c
HH-3F: B2I/d, IB2/c
WPB-95: B2I/c, IB2/c
(HH-3F and WPB-95 from B2 start after WPB from B1 arrives at I.)

D3

WMEC-210: B1I/c, IB2/c, B2B1/c
HH-3F: IB2/c
HH-3F (on WMEC-210) starts after WMEC-210 arrives at I.

(We assume that WMEC-210 will be able to support HH-3F although it is designed to support HH-52A, thus yielding a higher performance. HH-3F is heavier than HH-52A by about 7 tons and longer by about 10 feet).

C. Rankings and Ratios

Ranking and Ratio in Terms of Energy Consumption

R1	R2	Ranking	RE
5-20	0-2.4	D1, D2, D3	(D1, D2): 0.64-1.0
			(D1, D3): 0.15-0.27
5-20	2.4-5.0	D2, D1, D3	(D2, D1): 0.72-1.0
			(D2, D3): 0.17-0.27

Ranking and Ratio in Terms of Response Time

R1	R2	Ranking	RT
5-20	0-1.67	D1, D2, D3	(D1, D2): 0.96-1.0
			(D1, D3): 0.65-0.79
5-20	1.67-5	D2, D1, D3	(D2, D1): 0.92-1.0
			(D2, D3): 0.66-0.79

D. Findings

1. In terms of energy consumption, D1 is best for R1 = 5-20 and R2 = 0-2.4; while D2 is best for R1 = 5-20 and R2 = 2.4-5

2. In terms of response time D1 is best for R1 = 5-20, R2 = 0-1.67; while D2 is best for R1 = 5-20, R2 = 1.67-5.0.

3. Thus, in regions R1 = 5-20 and R2 = 0-1.67, D1 is best in terms of energy consumption and response time. In region R1 = 5-20 and R2 = 2.4-5, D2 is always the best alternative.

TABLE V-12

Comparative Analysis of Scenario 5

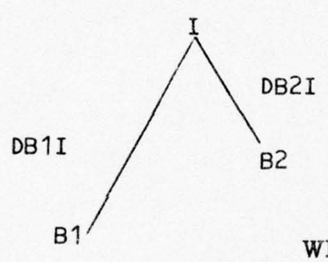
Mission: MEP (oil spill)
Time: 1980

A. Description

A freighter has collided with a large oil tanker just off the coast of Louisiana, resulting in a major spill.

A typical spill response involves at least one surface or air vehicle for delivery of initial spill clean up equipment, usually an oil "fence" or other containment device, plus two identical vehicles with an oil recovery barge for performing the actual cleanup operation. (See diagram below.) Initial response must be rapid to contain the spill and aircraft or high performance surface craft would be used. Cleanup operations would typically utilize a pair of tugs or tenders.

B. Alternatives and Tactics



$$R = \frac{DB2I}{DB1I}$$

We assume: $0 \leq R \leq 5$.

E1

HH-3F: B1I/c, IB1/c
WLR: B1I/c, IB2/1, B2B1/c
(Two WLR vehicles are used for oil recovery.)

E2

Same as above with skycrane instead of HH-3F and harbor tugs instead of WLR's.

E3

As E1 with MRS instead of HH-3F.

C. Rankings and Ratios

Ranking and Ratio in Terms of Energy Consumption

R	Ranking	RE
0-5	E3, E1, E2	(E3, E1): 0.95-0.98 (E3, E2): 0.81-0.91

Ranking and Ratio in Terms of Response Time

E1, E2, E3 are identical

D. Findings

1. E3 is the best alternative in terms of energy consumption.
2. In terms of response time, no preference ordering exists.

TABLE V-13

Comparative Analysis of Scenario 6

Mission: Patrol
Time: 1980

A. Description

A general patrol operation is analyzed in terms of the time involved for patroling a fixed area. Patrol may use surface craft or aircraft. Only aerial vehicles are included in this analysis.

An important parameter which is specific to the vehicle is "field of view", which is a measure of the area visible from a fixed location. The analysis assumes that all patrol vehicles, are equipped with radar. It should be mentioned that the patrol analysis is rather simplistic in comparison to the incident mission analysis.

B. Vehicle Alternatives - Aircraft

F1

MRS: S/1

F2

HC-130: S/1

F3

HH-3F: S/1

F4

HH-X: S/1
S = search area
1 = loiter speed
S/1 = coverage of area S at speed 1
(HH-X is planned replacement for HH-52)

C. Ranking and Ratios

Ranking and Ratios in Terms of Energy Consumption

Ranking	RE
F4, F1, F3, F2	(F4, F1): 0.8
	(F4, F2): 0.5
	(F4, F2): 0.26

Ranking and Ratio in Terms of Response Time

Ranking	RT
F1, F2	(F1, F3): 0.35
F3, F4	(F1, F4): 0.35

(F1, F2 have the same rank; so do F3, F4).

D. Findings

1. In terms of energy consumption, F4 is best.

2. In terms of response time, F1 and F2 are identical; so are F3 and F4, but F1, F2 are better alternatives than either F3 or F4.

5. Comparative Analysis of Six Scenarios for 1990

The analysis for 1990 was done for two cases:

Case 1: Scenario description, vehicle alternatives and tactics are assumed identical to those for 1980 but the energy consumption of the vehicles is lowered by using the multipliers shown in Table V-6.

Case 2: Scenario descriptions are assumed identical to those for 1980, however, vehicle alternatives and tactics include new/advanced vehicles such as the hydrofoil.

The analysis for Case 1 shows that the rankings do not change when compared to the 1980 rankings; however, the ratios do change - energy ratios by 2% to 4%, and response time ratio by 4% to 8%. Case 2 analysis involves analyzing six additional scenarios.

The results are summarized in Tables V-14 through V-19.

TABLE V-14

Comparative Analysis of Scenario 7

Mission: Search (rescue)
Time: 1990

A. Description

Identical to Scenario 1 (Table 5-8)

B. Alternatives and Tactics

a1

ACV-1: BI/c, IB/c
HH-3F: BI/d, IB/c

a2

HH-3F (on SES-2): PI/d, IB/c
SES-2: PI/c, IB/c

a3

HH-3F: BI/d, IB/c
HYD-JET: PI/c, IB/c

a4

HH-3F: BI/d, IB/c
Planing Craft: BI/c, IB/c

C. Ranking and Ratios

Ranking and Ratios in Terms of Energy Consumption

R	Ranking	RE	
0-1.4	a3, a1, a2, a4	(a3, a1):	0.52-0.89
		(a3, a2):	0.4-0.52
		(a3, a4):	0.23-0.4
1.4-1.8	a3, a1, a4, a2	(a3, a1):	0.89-1.0
		(a3, a4):	0.4-0.45
		(a3, a2):	0.39-0.4
1.8-5	a1, a3, a4, a2	(a1, a3):	0.53-1.0
		(a1, a4):	0.45
		(a1, a2):	0.18-0.39

Ranking and Ratios in Terms of Response Time

R	Ranking	RT
0-1.5	a2, a1, a4, a3	(a2, a1): 0.4-1.0
		(a2, a4): 0.27-0.68
		(a2, a3): 0.25
1.5-2.7	a1, a2, a4, a3	(a1, a2): 0.68-1.0
		(a1, a4): 0.68
		(a1, a3): 0.17-0.25
2.7-5.0	a1, a4, a2, a3	(a1, a4): 0.68
		(a1, a2): 0.42-0.68
		(a1, a3): 0.1-0.17

D. Findings

1. In terms of energy consumption, a3 is the best alternative for R=1.8-5.0. a1 is the best alternative for R=0-1.8.

2. In terms of response time, a2 is the best alternative for R=0-1.5. a1 is the best alternative for R=1.5-2.7.

3. Thus, a1 is always best when R=1.8-5.0

TABLE V-15

Comparative Analysis of Scenario 8

Mission: SAR (search)
Time: 1990

A. Description

Identical to 1980 (See Table V-9).

B. Alternatives and Tactics

Lighter-Than-Air vehicles seem to be the only new airborne platform for this 1990 mission.

b1 LTAV: PI/d, S/l

Since there is only one alternative, no comparison analysis is performed for the 1990 SAR (search).

TABLE V-16

Comparative Analysis of Scenario 9

Mission: ELT (fisheries)
Time: 1990

A. Description

Identical to 1980 (See Table V-10.

B. Alternatives and Tactics

c1*

HH-3F (on SWATHS): P1I/d, IP1/c
SWATHS: P1I/c, IB/c

c2

HYD-PHM; P1I/d, IB/c

c3

LTAV (2000 mile range): P2I/d, I/1
WPB-95: P1I/c, IB/c
(LTAV loiters at I until the arrival of WPB-95)

c4

MRS: P2I/d, I/1
SES-1: P1I/d, IB/c
(MRS loiters at I until the arrival of SES-1).

C. Ranking and Ratio

Ranking and Ratio in Terms of Energy Consumption

R1, R2 Bounds	Ranking	RE
$R2 \leq (3.2\ R1) - 1.3$	c3, c4, c2, c1	(c3, c4): 0.24-0.5
		(c3, c2): 0.24-0.5
		(c3, c1): 0.08-0.25
$(3.2\ R1)-1.3 \leq R2 \leq (6.6\ R1)+2.2$	c3, c2, c4, c1	(c3, c2): 0.2-1.0
		(c3, c4): 0.15-0.66
		(c3, c1): 0.04-0.36
$R2 \geq (6.6\ R1)+2.2$	c2, c3, c4, c1	(c2, c3): 0.5-1.0
		(c2, c4): 0.39-0.65
		(c2, c1): 0.22-0.35

* We assume that SWATHS will be designed to support HH-3F

Ranking and Ratio in Terms of Response Time

R1	R2	Ranking	RT
0-5	0-5	c4, c2, c1, c3	(c4, c2): 0.24-0.65 (c4, c1): 0.18-0.48 (c4, c3): 0.16-0.23

D. Findings

1. In terms of energy consumption, c3 is best when $R2 \leq (3.2\,R1) - 1.3$ and $(3.2R1)\ 1.3 \leq R2 \leq (6.6R1) + 2.2$; c2 is best when $R2 \geq (6.6R1) + 2.2$.

2. c4 is the best alternative in terms of response time.

TABLE V-17

Comparative Analysis of Scenario 10

Mission: ELT (smuggling)
Time: 1990

A. Description

Identical to 1980 (See Table V-11).

B. Alternatives and Tactics

d1

ACV-2: B1I/1, IB1/c
HH-3F: B2/c
(HH-3F starts after ACV-2 arrives at I)

d2

SES-2: B1I/1, IB1/c
HH-3F (on SES-2): IB2/c

d3

SWATHS: B1I/1, IB1/c
HH-3F (on SWATHS): IB2/c

C. Ranking and Ratios

Ranking and Ratios in Terms of Energy Consumption

R	Ranking	RE
5-20	d1, d2, d3	(d1, d2): 0.88-0.89 (d1, d3): 0.82-0.83

Ranking and Ratios in Terms of Response Time

R	Ranking	RT
5-20	d1 or d2, d3	(d1 or d2, d3): 0.13

D. Findings

1. d1 is the best alternative in terms of energy consumption.
2. d1 and d2 are both best alternatives in terms of response time.
3. Thus, d1 is always the best alternative.

TABLE V-18

Comparative Analysis of Scenario 11

Mission: MEP
Time: 1990

A. Description

Identical to 1980 (See Table V-12).

B. Alternatives and Tactics

e1

ACV-1: B1I/c, IB1/c
2 Harbor Tugs: B1I/c, IB2/1, B2B1/c

e2

HH-3F: B1I/c, IB1/c
2 SES-2: B1I/c, IB2/1, B2B1/c

e3

HH-3F: B1I/c, IB1/c
2 SWATHS: B1/c, IB2/1, B2B1/c

C. Ranking and Ratios

Ranking and Ratios in Terms of Energy Consumption

R	Ranking	RE
0-2.4	e1, e2, e3	(e1, e2): 0.21-0.44
		(e1, e3): 0.21-0.22
2.4-5	e1, e3, e2	(e1, e3): 0.21
		(e1, e2): 0.16-0.21

Ranking and Ratios in Terms of Response Time

R	Ranking	RT
0-5	e2, e3, e1	(e2, e3): 0.25-0.94
		(e2, e1): 0.12-0.38

D. Findings

1. In terms of energy consumption, e1 is the best alternative.

2. In terms of response time, e2 is the best alternative.

TABLE V-19

Comparative Analysis of Scenario 12

Mission: Patrol
Time: 1990

A. Description

Identical to 1980 (See Table V-13).

B. Alternatives

f1: LTAV (2000 mile range)

Since there is only one alternative in the year 1990, no comparative analysis was carried out for this year.

The f1 alternative is used for the cross comparison between the 1980 alternatives and the f2 - 1990 alternative.

6. Comparative Analysis of Scenarios for 2000

We choose to analyze one scenario - ELT (smuggling) - to study the impact of non-vehicle technology; in this case, surveillance by means other than the vehicles. The results are summarized in Table V-20.

TABLE V-20

Comparative Analysis of Scenario 13

Mission: ELT (smuggling)
Time: 2000

A. Description

Same as 1980 but we assume that the smugglers utilize vehicles having the same high performance as that of the Coast Guard vehicles so that only the new/advanced vehicles are considered.

B. Alternatives and Tactics

Z1

HYD-JET: PI/d, IB/c

Z2

SES-2: BI/d, IB/c

C. Rankings and Ratios

Rankings and Ratios in Terms of Energy Consumption

R	Ranking	RE
0-1.7	Z1, Z2	(Z1, Z2): 0.15-1.0
1.7-5.0	Z2, Z1	(Z2, Z1): 0.37-1.0

Rankings and Ratios in Terms of Response Time

R	Ranking	RT
0-5.0	Z2, Z1	(Z2, Z1): 0.21-0.46

D. Findings

1. In terms of energy consumption, Z1 is the best alternative for R = 0-1.7 and Z2 is the best alternative for R = 1.7-5.0.

2. In terms of response time, Z2 is the best alternative.

7. Comparison of Best 1980 and 1990 Alternatives

In this section, we present the results of comparing the best alternatives for 1980 and 1990, for the six scenarios. We utilize as inputs the results presented in Table V-8 through V-13 for 1980 and Tables V-14 through V-19 for 1990. These are listed in Tables V-21 to V-26 under "A". The cross-year comparison (1980 and 1990) yields the results shown in Tables under "B".

TABLE V-21

Comparative Analysis of Best Alternatives for 1980 and 1990 - Scenarios 1 and 7

Mission: SAR (rescue)

A. Best Alternatives from Previous Analysis

Year	Energy Consumption	Response Time
1980	A4 (Table V-8)	A1 (Table V-8)
1990	a1, a3 (Table V-14)	a1, a2 (Table V-14)

B. Ranking and Ratios of Cross Year Comparison

Ranking and Ratios in Terms of Energy Consumption

R	Ranking	RE
0-1.8	A4, a3, a1	(A4, a3): 0.43-0.72
		(A4, a1): 0.73-0.93
1.8-5.0	A4, a1, a3	(A4, a1): 0.28
		(A4, a3): 0.15-0.28

Ranking and Ratios in Terms of Response Time

R	Ranking	RT
0-1.5	a2, a1, A1	(a2, A1): 0.4-1.0
		(a2, A1): 0.29
1.5-5.0	a1, a2, A1	(a1, a2): 0.72-1.0
		(a1, A1): 0.12-0.29

C. Findings

1. A4 is the best alternative, in terms of energy consumption.

2. In terms of response time, a2 is best for R=0 - 1.5 and a1 is best when R=1.5 - 5.0.

TABLE V-22

Comparative Analysis of Best Alternatives
for 1980 and 1990 - Scenarios 2 and 8

Mission: SAR (search)

A. Best Alternatives from Previous Analysis

Year	Energy Consumption	Response Time
1980	B3 (Table V-9)	B1 (Table V-9)
1990	b1 (Table V-15)	b1 (Table V-15)

B. Ranking and Ratios of Cross-Year Comparison

In Terms of Energy Consumption			In Terms of Response Time	
R	Ranking	RE	Ranking	RT
0-5	B3, b1	0.18-0.22	B1, b1:	0.21-0.29

C. Findings

1. In terms of energy consumption, B3 is the best alternative

2. In terms of response time, B1 is the best alternative.

TABLE V-23

Comparative Analysis of Best Alternatives for 1980 and 1990: Scenarios 3 and 9

Mission: ELT (fisheries)

A. Best Alternatives from Previous Analysis

Year	Energy Consumption	Response Time
1980	C4 (Table V-10)	C1 (Table V-10)
1990	c2, c3 (Table V-16)	c4 (Table V-16)

B. Ranking and Ratios of Cross-Year Comparison

Ranking and Ratios in Terms of Energy Consumption

R2	Ranking	RE
$R2 \leq -1.8R1+1.73$	c3, C4, c2	(c3, C4): 0.35-1.0 (c3, c2): 0.2-0.82
$-1.8R1+1.73 \leq R2 \leq 6.6R1+2.2$	C4, c3, c2	(C4, c3): 0.44-1.0 (C4, c2): 0.27-0.77
$R2 \leq 6.6R1+2.2$	C4, c2, c3	(C4, c2): 0.53-1.0 (C4, c3): 0.53-1.0

Ranking and Ratios in Terms of Response Time

R1	R2	Ranking	RT
0-5	0-5	c4, C1	(c4, C1): 0.33-0.59

C. Findings

1. In terms of energy consumption, c3 is best when $R2 \leq -1.85\ R1 + 1.73$, while C4 is best when $R2 \geq -1.8\ R1 + 1.73$
2. c4 is the best alternative in terms of response time.

TABLE V-24

Comparative Analysis of Best Alternatives for 1980 and 1990: Scenarios 4 and 10

Mission: ELT (smuggling)

A. Best Alternative from Previous Analysis

Year	Energy Consumption	Response Time
1980	D1, D2 (Table V-11)	D1, D2 (Table V-11)
1990	d1 (Table V-17)	d1 (Table V-17)

B. Ranking and Ratio Bounds of Cross Year Comparison

Ranking and Ratio Bounds in Terms of Energy Consumption

R1	R2	Ranking	RE
5-20	0-2.4	D1, D2, d1	(D1, D2): 0.64-1.0
			(D1, d1): 0.23-0.29
5-20	2.4-5	D2, D1, d1	(D2, D1): 0.72-1.0
			(D2, d1): 0.24-0.29

Ranking and Ratio Bounds in Terms of Response Time

R1	R2	Ranking	RT
5-20	0-1.7	d1, D2, D1	(d1, D2): 0.18-0.21
			(d1, D1): 0.18-0.21
5-20	1.7-5	d1, D1, D2	(d1, D1): 0.18-0.21
			(d1, D2): 0.18-0.21

C. Findings

1. In terms of energy consumption, D1 is best for R1=5-20, R2=0-2.4, while D2 is best for R1=5-20, R2=2.4-5.0

2. In terms of response time, d1 is always best.

TABLE V-25

Comparative Analysis of Best Alternatives for 1980 and 1990: Scenarios 5 and 11

Mission: MEP (oil spill)

A. Best Alternative from Previous Analysis

Year	Energy Consumption	Response Time
1980	E3 (Table V-12)	E3 (Table V-12)
1990	e1 (Table V-18)	e2 (Table V-18)

B. Rankings and Ratios of Cross Year Comparison

	In Terms of:			
	Energy Consumption		Response Time	
R	Ranking	RE	Ranking	RT
0-5.0	E3, e1	(E3,e1):0.69-0.88	e2, E3	(e2, e3):.06-.36

C. Findings

1. E3 is best in terms of energy consumption.

2. e2 is best in terms of response time.

TABLE V-26

Comparative Analysis of Best Alternatives for 1980 and 1990: Scenarios 6 and 12

Mission: Patrol (surveillance)

A. Best Alternatives from Previous Analysis

Year	Energy Consumption	Response Time
1980	F1, F4	F1, F4
1990	f1	f1

B. Ranking and Ratio Bounds of Cross Year Comparison

In Terms of:

Energy Consumption		Response Time	
Ranking	RE	Ranking	RT
f1, F4, F1	(f1,F4): 0.68 (f1,F1): 0.58	F1, F4, f1	(F1,F4): 0.33 (F1,f1): 0.33

C. Findings

1. f1 is best in terms of energy consumption.

2. F1 is best in terms of response time.

8. Comparison of Best Alternatives for 1980, 1990, and 2000 for ELT (Scenarios 4, 10, and 13)

(a) Best Alternatives

Table V-24 shows the best alternatives among 1980 and 1990 alternatives as D1, D2 in terms of energy consumption and d1 in terms of response time. Table V-20 shows Z1 as the best alternative for 2000 in terms of energy consumption and Z2 in terms of response time.

(b) Rankings and Ratios

Rankings and Ratios in Terms of Energy Consumption

R1	R2	Ranking	RE	
5.0-7.8	0-5	D2, D1, d2	(D2, Z2):	0.87-0.88
7.8-20	0-5	Z2, D2, D1	(d2, D2):	0.8-0.89

Rankings and Ratios in Terms of Response Time

R1	R2	Ranking	RT	
5-20	0-5	Z2, d1	(Z2, d1):	0.08-0.3

(c) Findings

1. In terms of energy consumption, D2 is the best for R1= 5.0-7.8, R2=0-5, while Z2 is best for R1=7.8-20, R2=0-5.

2. In terms of response time, Z2 is best.

9. Summary and Implications

The results of the analyses presented in previous sections are summarized in Tables V-27 and V-28. In the summary tables, we indicate the vehicle mixes which were found to be the best in terms of tactics (primarily speed profile) and relative locations to perform the mission. It is recalled that, in certain cases, an alternative was found to be best only for a certain range of normalized distances (R, R1, R2). The summary in Tables V-27 and V-28, however, has been simplified to indicate the best vehicle mixes, without showing the applicable range of normalized distance. The interested reader can refer to appropriate tables in previous sections to obtain this information.

Several implications emerge from the analyses as significant. These are summarized below.

* It was stated earlier (Chapter IV) that new vehicles are unlikely to be energy savers. The Level 3 analysis quantitatively illustrates the statement as well as the trade-offs involved. Tactics employing the existing vehicles differ substantially from those utilizing new/advanced vehicles in terms of energy consumption, by a margin of 11% to 80%, as shown in Table V-21 through V-26.

* Level 3 analysis clearly indicates that the choice of tactics, including the choice of vehicles, to perform a given mission yields considerable energy savings, but these are obtained at the expense of the response time. Thus, in most instances prudent planning of tactics by the Coast Guard is a major way to lower energy consumption.

* Tactics employing new/advanced vehicles generally yield better response times than those employing current vehicles. Again, this was pointed out earlier in Chapter IV. The Level 3 analysis quantitatively illustrates that differences in response times are substantial between the tactics employing existing and advanced vehicles. (Table V-27).

* The analysis shows that, in general, there are trade-offs between saving energy and responding quickly. In essence, these tradeoffs involve choice of "optimal" speed profile which produces the best compromise between energy consumption and response time. The trade-offs may be important depending upon the mission.

* The analysis shows that improved response times can be realized by combining the use of existing and new vehicles (e.g., HH-3F with SES or Hydrofoil) in some cases. In missions such as SAR and ELT where response time is perhaps more important than energy consumption, use of such tactics may be especially important. (Table V-26).

* The Lighter-Than-Air Vehicle (LTAV) appears to be an especially important vehicle for lowering energy consumption. Most of the tactics utilizing LTAV display lower energy consumption. Further, LTAV with 2000 mile range also displays good response times when used as vehicles for search and patrol. (Table V-26).

TABLE V-27

SUMMARY: BEST ALTERNATIVES (Vehicle Mixes) FOR 1980 and 1990

	IN TERMS OF ENERGY CONSUMPTION		IN TERMS OF RESPONSE TIME	
	1980	1990	1980	1990
SAR (Rescue)	A4 : HH-52, MLB	a1 : HH-3F, ACV-1 a3 : HH-3F, Hydrofoil (Jetfoil)	A1 : HH-3F, WMEC-210 A4 : HH-52	a1 : HH-3F, ACV-1 a2 : HH-3F, SES-2
SAR (Search)	B3 : Cessna	b1 : LTAV (1000 mile range)	B1 : MRS B4 : HC-130	b1 : LTAV (1000 mile range)
ELT (Fisheries)	C4 : Cessna, HH-3F, WHEC - 378	C2 : Hydrofoil (PHM) C3 : LTAV	C1 : MRS, HH-3F, WHEC - 378	C4 : MRS, SES-1
ELT (Smuggling)	D1 : HH-3F, WPB-95 D2 : HH-3F, WPB-95 (D1, D2 differ in terms of tactics employed)	d1 : HH-3F, ACV-2	D1 : HH-3F, WPB-95 D2 : HH-3F, WPB-95	d1 : HH-3F, ACV-2 d2 : HH-3F, SES-2 (d1, d2 have identical response time)
MEP (Oil spill)	E3: MRS, WLR	e1 : ACV-1, Harbor Tug	E1 : HH-3F, WLR E2 : Sky Crane, Harbor Tug E3 : MRS, WLR (E1, E2, E3 have identical response time)	e2 : HH-3F, SES-2
Patrol (Aircraft)	F4: HH-X *	f1 : LTAV (2000 mile range)	F1 : MRS F2 : HC-130 (F1, F2 have identical response time)	f1 : LTAV (2000 mile range)

* Planned addition

TABLE V-28

SUMMARY: COMPARISON OF BEST 1980 and BEST 1990 ALTERNATIVES (Vehicle Mixes)

	In Terms of Energy Consumption		In Terms of Response Time	
MISSION	Best Alternative(s)	RE*	Best Alternative(s)	RT*
SAR (Rescue)	A4 : HH-52, MLB	0.2 - 0.43	a1 : HH-3F, ACV-1 a2 : HH-3F, SES-2	0.11 - 1.0
SAR (Search)	B3 : Cessna	0.19 - 0.2	B1 : MRS	0.57 - 0.76
ELT (Fisheries)	C4 : Cessna, HH-3F, WHEC-378 c3 : LTAV (2000 miles), WPB-95	0.22 - 1.0	c4 : MRS, SES - 1	0.04 - 1.0
ELT (Smuggling)	D1 : HH-3F, WPB-95 D2 : HH-3F, WPB-95 D1, D2 differ in tactics employed)	0.23 - 0.29	d1 : HH-3F, ACV-2 d2 : HH-3F, SES-2 (d1,d2 have identical response times)	0.11 - 0.21
MEP (Oil spill)	E3 : MRS, WLR	0.27 - 0.39	e2 : HH-3F, SES-2	0.06 - 0.36
Patrol (Aircraft)	f1 : LTAV (2000 miles)	0.58	F1 : MRS	0.33

RE* is the range of the ratio of energy consumption of best energy alternative to the energy consumption of the best response time alternative. For example, RE* of 0.2 for SAR (Rescue) scenario means that the energy consumption of A4 at best is 20% of either a1 or a2. Similarly, RT* is the range of the ratio of response time of the best response time alternative to the best energy consumption alternative. For example, RT* of 0.11 for SAR (Rescue) means that response time of a1 or a2 is at best 11% of the response time of A4.

AD-A079 320 NERO AND ASSOCIATES INC PORTLAND OR F/G 13/10
TECHNOLOGY ASSESSMENT OF LOW ENERGY VEHICLES.(U)
SEP 79 H A LINSTONE, R DAWSON, Y GUR DOT-CG-835030
UNCLASSIFIED TF019 USCG-D-64-79 NL

3 OF 4
AD
A079320

* From Table V-28, it is clear that the best alternatives in terms of energy consumption consume less energy than the best alternatives in terms of response time. (See the values of RE *). Similarly, the best alternatives in terms of response time respond quicker than the alternatives with lowest energy consumption. (See the values of RT*).

* In almost all cases considered in the Level 3 analysis, the best alternatives in terms of energy consumption are the 1980 alternatives (i.e., tactics primarily utilizing exisiting vehicles). In terms of response time, the best alternatives are almost always the 1990 alternatives (i.e., tactics primarily utilizing new/advanced vehicles).

* As pointed out earlier, "prudent" planning of Coast Guard missions requires exploring and analyzing the trade-offs between vehicle energy consumption and performance. (Response time was considered in the analysis; however, other parameters, e.g., survivability, endurance, can be substituted). Extension, elaboration and computerization of the model developed here for Level 3 analysis can become an important tool for planning the various missions. The model can allow the decision maker to choose tactics and vehicle mix by understanding the trade-offs between energy consumption and vehicle and mission performance.

E. Limitations of Energy Analysis

Energy analysis has been discussed from three different perspectives. Each perspective is like a window through which the merits of a vehicle become visible, at least from an energy and response time viewpoint. In interpreting and using the results of these analyses, the reader should note the key limitations which apply to the analyses.

Level 1 Analysis: Comparisons of Some Coast Guard Vehicles, involved examining each vehicle on its own merits, mainly in terms of its technical characteristics (design, performance, and operational). Requirements of specific missions were not explicitly considered in terms of the situational aspects of the mission. (This was done in the Level 3 analysis). The performance characteristics, e.g., endurance, and speed, were considered as surrogates of the mission requirements, assuming that a vehicle has been designed as a suitable platform to adequately match the requirements of the mission it is expected to serve. With this assumption, the results of Level 1 analysis are quite meaningful for relative comparisons of the various vehicles.

Further, we assumed in the Level 1 analysis that the vehicle operated in relatively calm weather conditions (e.g., smooth water for operating cutters). We did not analyze sensitivity of parameters, such as transport efficiency and specific energy, to changes in weather conditions. Such an analysis can be very useful and should be considered as a candidate for further work in this area.

Finally, as pointed out, it was essential that the vehicles be compared in a consistent and equitable manner. It seems inappropriate to compare vehicles without accounting for the applicable range of Froude number, medium of operation, and so on. This does not mean that the sea and air vehicles should not be considered together when judging the best means to conduct a mission. However, one must realize that vehicles cannot be designed to simultaneously minimize the Froude number and maximize their speed, at least with the current state-of-the-art.

Level 2 Analysis: Energy Analysis of Alternative Fuels addressed the issue of energy efficiency in producing and delivering alternate fuels for Coast Guard vehicles primarily those derived from coal and oil shale. The energy accounting approach used here required careful selection of the system boundaries within which the analysis was performed. Although, we accounted for most of the energy subsidies provided for the various stages of fuel production, transportation, and distribution, we did not include the efficiency of the vehicle in the accounting; i.e., efficiency by which the chemical energy contained in the fuel is converted into mechanical energy used to transport the vehicle. This was not possible because estimates of such efficiencies for major Coast Guard vehicles are not readily available. Within the bounds of Level 2 analysis as detailed in section C, the results describe the relative merits of the alternate fuels derived from coal and oil shale reasonably well.

Level 3 Analysis: Aggregate Analysis of Relevant Vehicles to Perform Selected Coast Guard Missions, involved an evaluation of vehicles within the requirements of specified missions. The evaluation was done in terms of energy consumption and response time. A series of scenarios were developed to depict primarily missions consisting of incident responses and the ways (tactics) in which the relevant vehicles are used for responding to the incidents. These scenarios are simplified versions of the real world and therefore, the results must be interpreted with care.

The Level 3 analysis has been designed to investigate the nature of the trade-offs between energy requirements and response time, which depended on the tactics used to perform the mission. It is not designed to develop precise answers to the questions regarding actual total energy consumption and response time requirements. The analysis shows that the choice of tactics (primarily the choice of vehicle and speed profile) can produce meaningful energy savings, depending upon the incident location or the area to be searched/patroled. An important contribution of Level 3 analysis has been the development of a novel technique (mathematical model) to study the trade-offs mentioned above.

Also, it is more than likely that the Coast Guard can respond to particular situations in a manner other than that delineated in the scenarios, although the choice of tactics used in Level 3 analysis seems reasonable to us. The model used for Level 3 analysis however is sufficiently flexible to accept different views of tactical choices if so desired.

As noted in section D, we have restricted the choice of vehicle speed to three discrete levels - loiter, cruise, and dash. We employ these labels to specify a speed profile ranging from a very low speed to the maximum designed speed. Again, departures from these specifications can be accommodated by the model used in Level 3 analysis. However, considering speed as a continuous variable would require extension of the model. It should be pointed out that the range of speed considered in Level 3 analysis does provide meaningful bounds within which a vehicle operates and the results also appear to be adequately bounded.

We did not undertake an analysis within the scope of this project to study the sensitivity of energy consumption and response time to changes in weather conditions. It can be argued, however, that changes in weather conditions primarily affect the speed profile. Thus, the sensitivity issue has been implicitly studied here and also in the Level 1 analysis. What is lacking is the exact association of changes in speed profile resulting from changes in weather conditions. We believe that such an analysis should be one of the candidates for further study.

Finally, a model to optimally choose vehicle mixes and associated tactics was developed. In this study, this method was applied to a limited number of scenarios, and conditions; however, it can be adapted and extended to evaluate vehicles in a much wider and/or different range of scenarios and conditions.

F. A Sensitivity Analysis of Total Energy Consumption for a Combination of Missions

What effect does a change in scenarios and Coast Guard priorities over time have on total fuel consumption? To obtain some clues we analyzed the energy demands for the three missions SAR, ELT, and MEP in the Scenarios X, Y, and Z.

Since we assume that in the next 15 years the Coast Guard fleet will be based largely on current vehicles, those used in this approximation were the current cutters and aircraft (but no boats). The time period is 1974-1995.

For the starting year 1974 we used data on the Coast Guard missions and fuel consumption from the Tetra Tech, Inc., report (Ref. 8) The average fuel consumption per mission (in gallons) for SAR, ELT, and MEP is shown in Table V-29.

In Table V-30 we note the number of missions in the year 1974.

In all the scenarios, we assumed the same rate of increase (or decrease) in the number of missions whether cutters or aircraft are involved.

In Table V-31 we present the annual rate of change of the number of missions in the three scenarios over the entire time span.

In all the scenarios and for all the missions we assume the same annual increase range of 2% to 4% in the period 1974 to 1980.

Scenario X: The surprise free scenario is characterized by a constant annual increase of 2% to 4% for all the missions in the period 1974-1995.

Scenario Y: In the external threat scenario for SAR missions, we assumed an annual decrease of 4% to 8% in the period 1980 to 1990 and an annual increase of 2% to 4% after 1990; for ELT missions, we assumed an annual increase of 6% to 12% in the period 1980 to 1990 and an annual decrease of 2% to 4% after 1990; and for MEP missions, we assumed an annual decrease of 4% to 8% in 1980 to 1990 and an annual increase of 2% to 4% after 1990.

Scenario Z: In the internal shift scenario for SAR missions, we assumed an annual decrease of 2% to 4% in 1980 to 1990; and for ELT missions we assumed an annual increase of 4% to 8% in 1980 to 1990 and an annual decrese of 2% to 4% after 1990.

The MEP mission changes in scenario Z are the same as in Scenario X.

The results of the fuel consumption analysis are shown in Figures V-13 to V-15.

Total fuel consumption (in millions of gallons) by cutters and aircraft for each mission in each scenario is given as a function of time (Figure V-13 to V-15).

The accumulated fuel consumption of all vehicles for all missions in each of the three scenarios is shown in Figure V-16.

TABLE V-29

AVERAGE FUEL CONSUMPTION PER MISSION (Gallons)

	CUTTERS	AIRCRAFT
SAR	731	497
ELT	8450	807
MEP	930	421

TABLE V-30

NUMBER OF 1974 MISSIONS

	CUTTERS	AIRCRAFT
SAR	6110	9764
ELT	459	1543
MEP	897	5166

TABLE V-31

ASSUMED RANGE OF ANNUAL INCREASE/DECREASE IN NUMBER OF MISSIONS

SCENARIO / MISSION	X			Y			Z		
	1977-1980	1980-1990	1990-1995	1977-1980	1980-1990	1990-1995	1977-1980	1980-1990	1990-1995
SAR	2% - 4% ↑	2% - 4% ↑	2% - 4% ↑	2% - 4% ↑	4% - 8% ↓	2% - 4% ↑	2% - 4% ↑	2% - 4% ↓	4% - 8% ↓
ELT	2% - 4% ↑	2% - 4% ↑	2% - 4% ↑	2% - 4% ↑	6% - 12% ↑	2% - 4% ↓	2% - 4% ↑	4% - 8% ↑	2% - 4% ↓
MEP	2% - 4% ↑	2% - 4% ↑	2% - 4% ↑	2% - 4% ↑	4% - 8% ↓	2% - 4% ↑	2% - 4% ↑	2% - 4% ↑	2% - 4% ↑

Increase = ↑

Decrease = ↓

FIGURE V-13

SAR FUEL CONSUMPTION

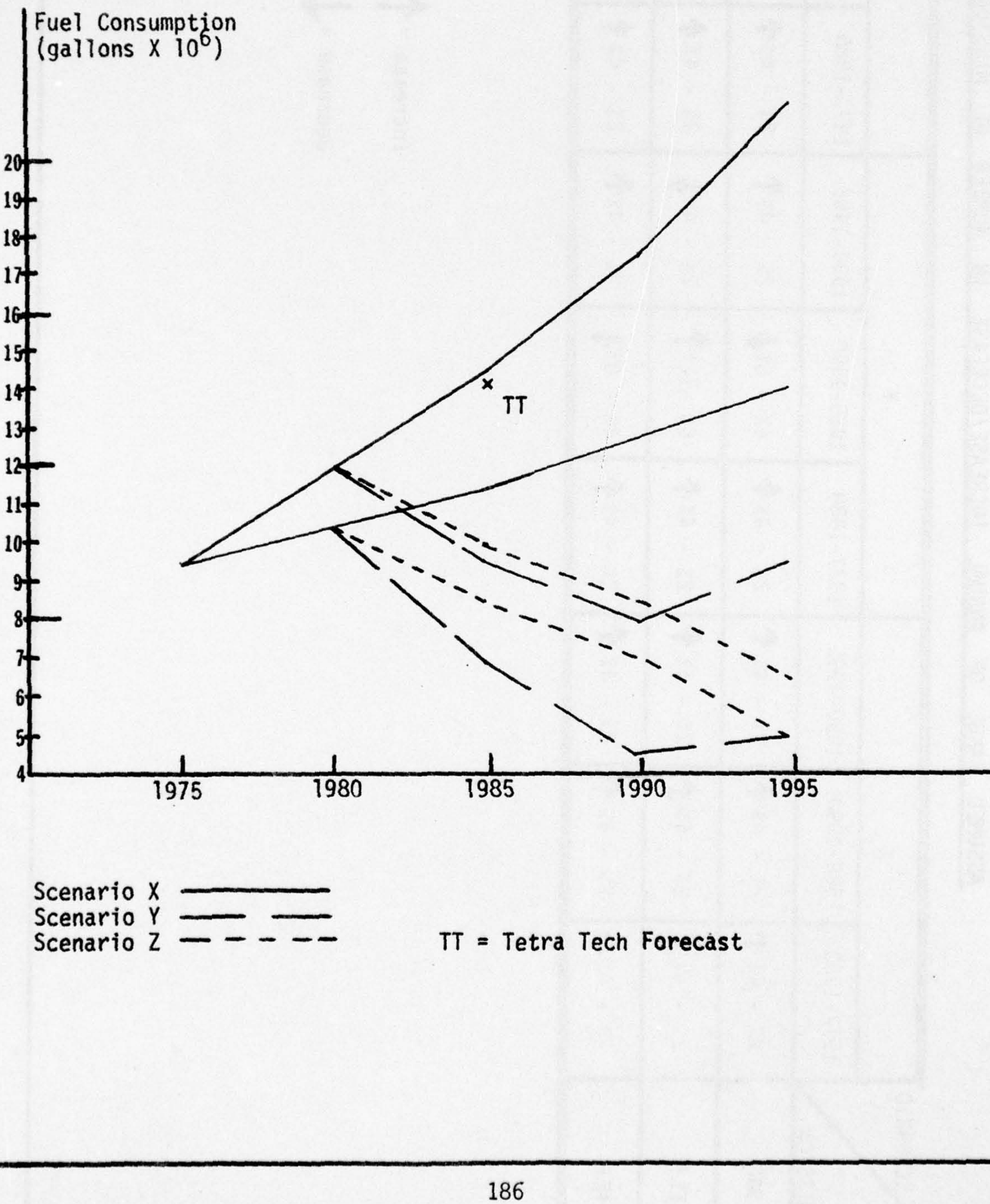


FIGURE V-14

ELT FUEL CONSUMPTION

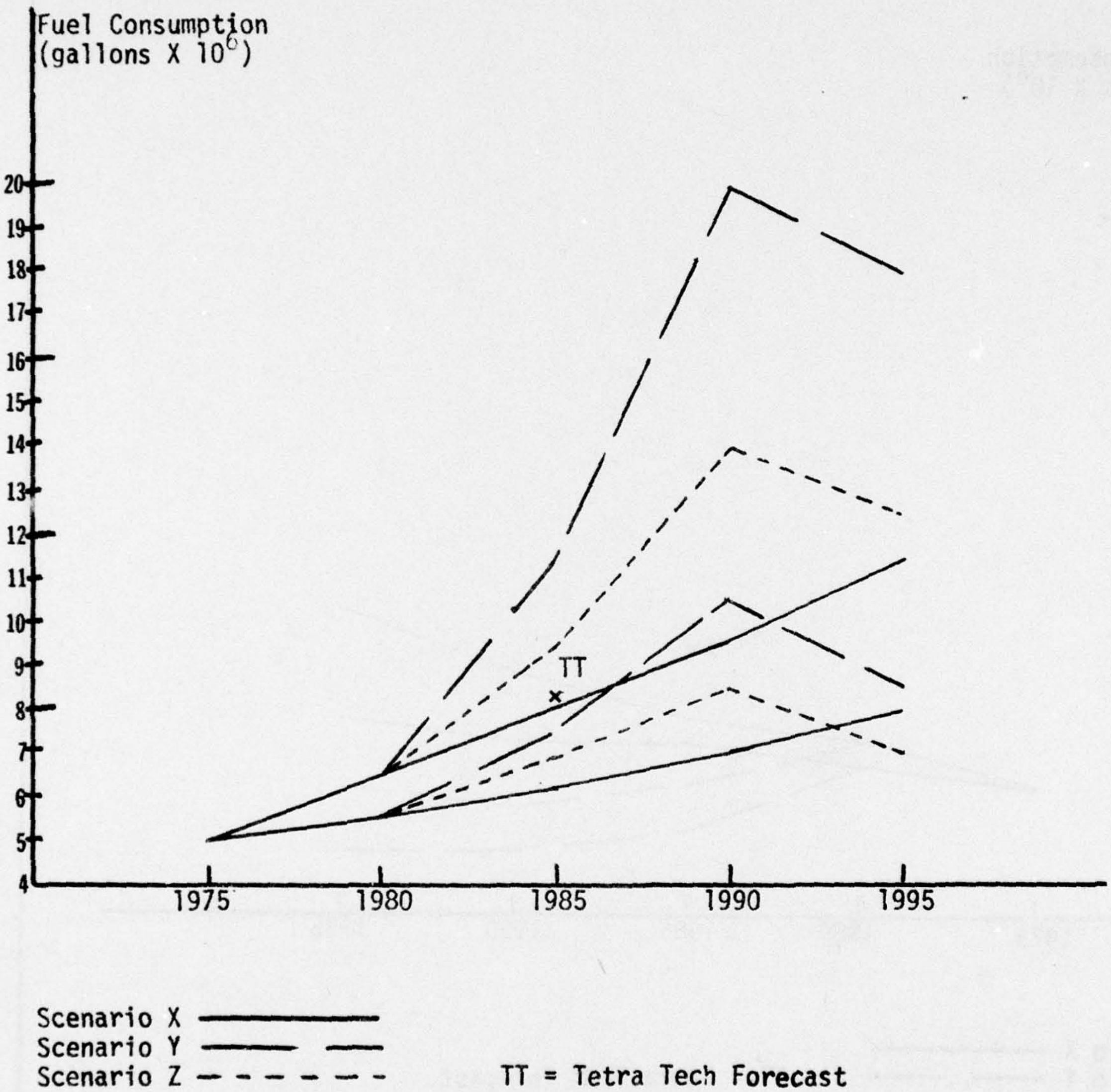


FIGURE V-15

MEP FUEL COMSUMPTION

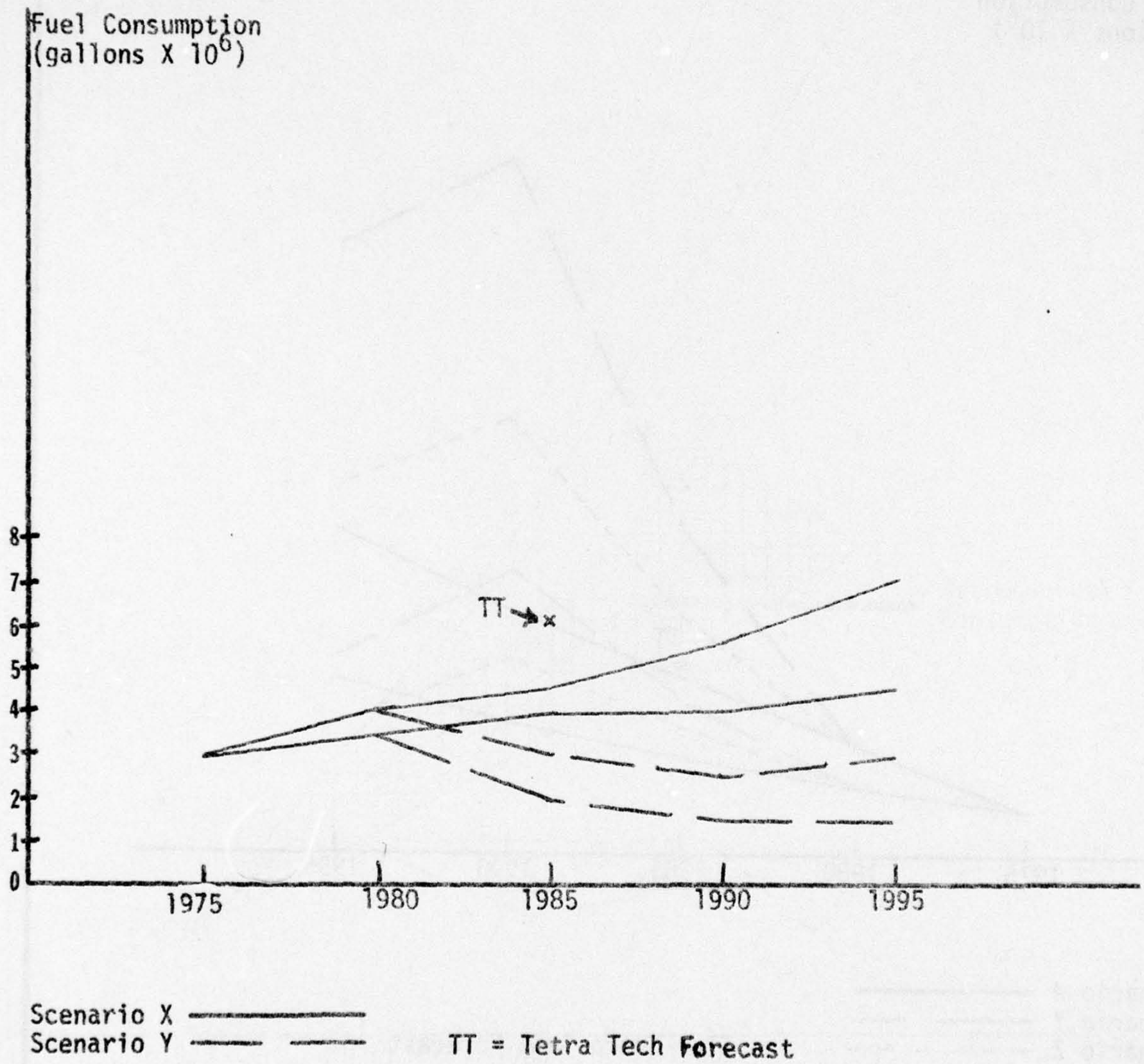
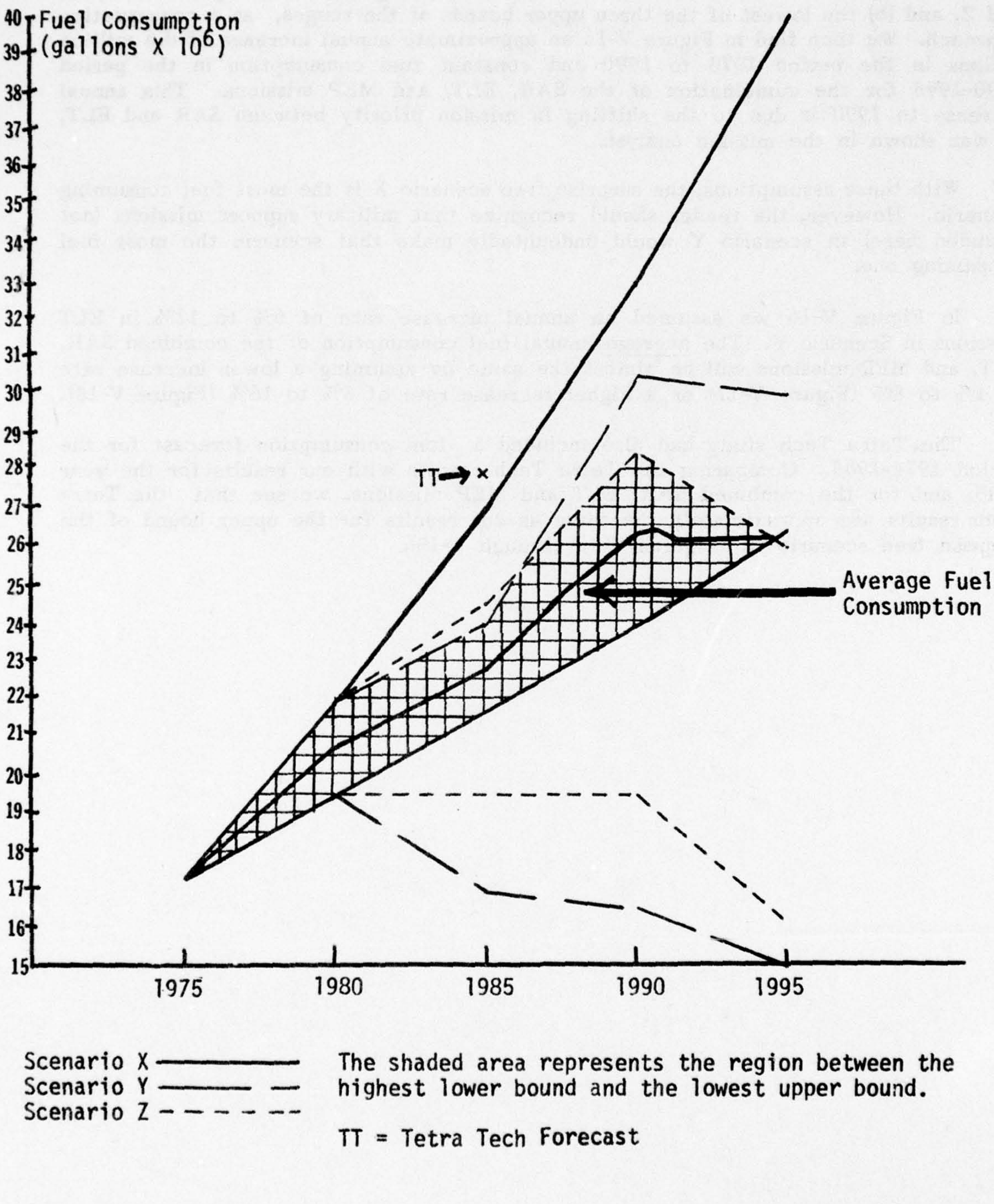


FIGURE V-16

TOTAL FUEL CONSUMPTION OF SAR, ELT AND MEP COMBINED
(annual increase rate of 6% - 12% for ELT)



It is obvious that the difference between the maximum and minimum fuel consumption increases as a function of time (according to the assumption regarding the annual rates). Assuming that each of the three scenarios has the same probability of occurrence, and using the min-max principle in each year, we use the average of (a) the highest of the three lower bounds of the ranges of consumption in X, Y, and Z, and (b) the lowest of the three upper bounds of the ranges, as a conservative approach. We then find in Figure V-16 an approximate annual increase of 0.6 million gallons in the period 1974 to 1990 and constant fuel consumption in the period 1990-1995 for the combination of the SAR, ELT, and MEP missions. This annual increase to 1990 is due to the shifting in mission priority between SAR and ELT, as was shown in the mission analysis.

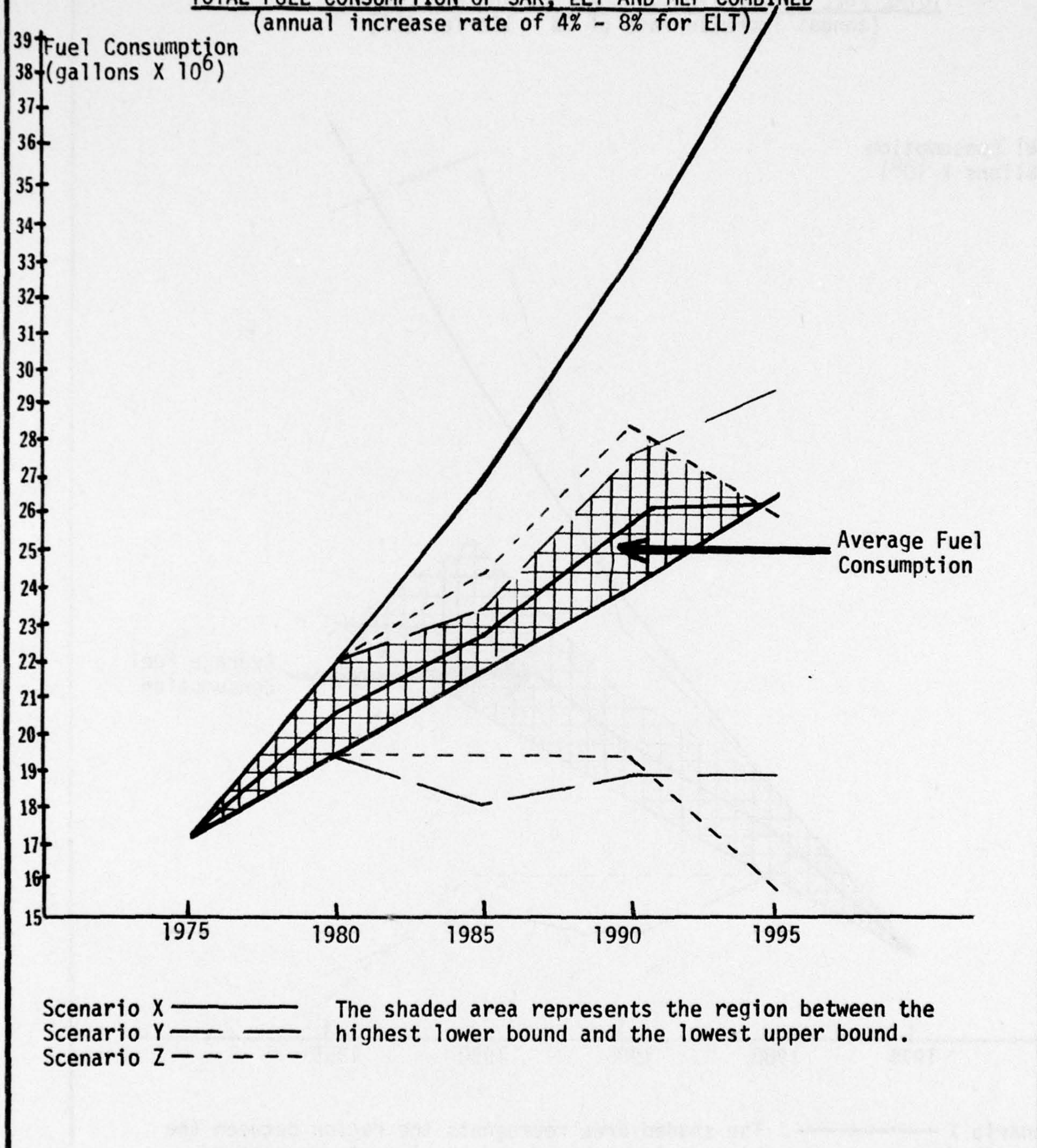
With these assumptions, the surprise free scenario X is the most fuel consuming scenario. However, the reader should recognize that military support missions (not included here) in scenario Y would undoubtedly make that scenario the most fuel consuming one.

In Figure V-16 we assumed an annual increase rate of 6% to 12% in ELT missions in Scenario Y. The average annual fuel consumption of the combined SAR, ELT, and MEP missions will be almost the same by assuming a lower increase rate of 4% to 8% (Figure V-17) or a higher increase rate of 8% to 16% (Figure V-18).

The Tetra Tech study had also included a fuel consumption forecast for the period 1974-1985. Comparing the Tetra Tech results with our results for the year 1985, and for the combined SAR, ELT and MEP missions, we see that the Tetra Tech results are approximately the same as our results for the upper bound of the surprise free scenario X. (Figures V-12 through V-15).

FIGURE V-17

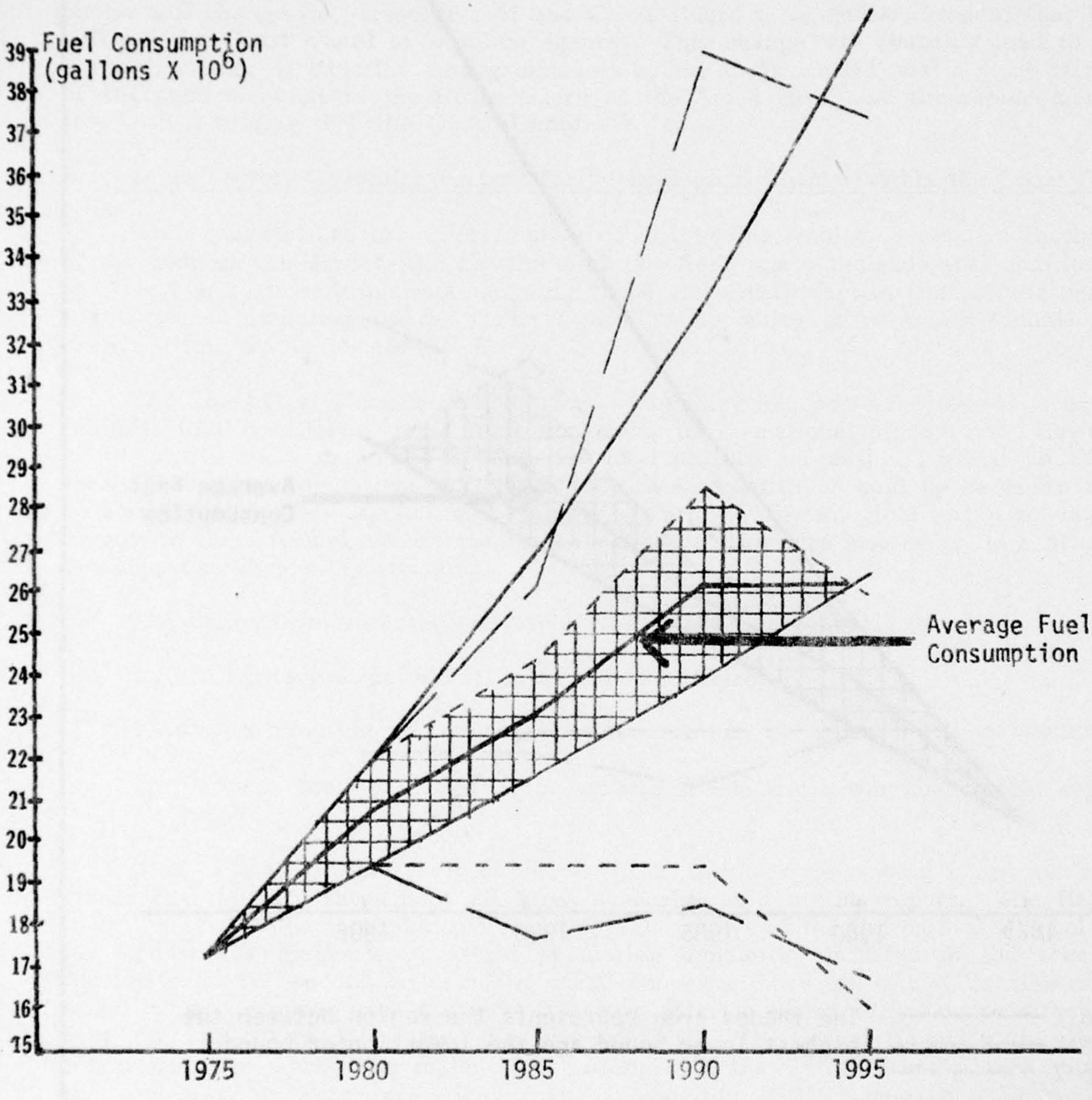
TOTAL FUEL CONSUMPTION OF SAR, ELT AND MEP COMBINED
(annual increase rate of 4% - 8% for ELT)



The shaded area represents the region between the highest lower bound and the lowest upper bound.

FIGURE V-18

TOTAL FUEL CONSUMPTION OF SAR, ELT AND MEP COMBINED
(annual increase rate of 8% - 16% for ELT)



Scenario X
Scenario Y
Scenario Z

The shaded area represents the region between the highest lower bound and the lowest upper bound.

REFERENCES

1. Congressional Research Service, Energy Accounting as a Policy Analysis Tool, Prepared for the Subcommittee on Energy Research, Development and Demonstration, June, 1976.
2. Dickson, E. M, et al., Impacts of Synthetic Liquid Fuel Development - Automative Market, Volumes I, II, and III, report by Stanford Research Institute, For ERDA & EPA, July, 1976.
3. Jewell, D. A., Energy Efficiency of Sea and Air Vehicles, Report no. CG-D-15-79, August, 1978.
4. Jane's All the World's Aircraft, Jane's Fighting Ships, Jane's Surface Skimmers, McGraw Hill Company, New York, Various editions.
5. Mandel, P., Water, Air, and Interface Vehicles, First Edition, MIT Press, 1969.
6. Mittal R. K., Effects of Energy Constraints on Transportation Systems, Proceedings of the Fourth National Conference held at Union College, Schenectady, December, 1977.
7. Steele, R., K. Sharma and E. M. Dickson, Synthetic Liquid Fuels Development, Assessment of Critical Factors, Volume IV: Energy and Economic Comparison of Coal-based Alternative Energy Supply Systems, a report by ERDA by Stanford Research Institute, May, 1977.
8. Tetra Tech, Inc., U.S. Coast Guard Energy Research and Development Program Plan, Volume I and II, report prepared for the U.S. Coast Guard, August, 1975.

VI. ORGANIZATIONAL ANALYSIS: FUTURE STATES OF THE COAST GUARD

A. Major Factors Modeled

In applying the SOPA technique* (Ref. 1) to the analysis of the projected future states of the Coast Guard, three basic factors need to be considered. These are: (1) the character of the fleet mix; (2) problems that accompany the implementation of new technologies and tactical applications of technologies; and (3) the weightings assigned to Coast Guard missions. All three of these factors have been considered in previous chapters of this report. In this chapter we will consider the organizational implications of the various combinations of the three factors developed above.

With respect to the character of the fleet mix, this organizational analysis will examine the projected mix in 1990 and 2000 in terms of two possibilities: Case A in which all vehicles considered available for use in the technological forecast for that year (Chapter IV) are available and potentially in use; and Case B in which the fleet mix consists of those vehicles most likely to be part of the fleet mix as determined by the optimization of missions as projected in Chapter III.

The second factor concerns the role of command support for the adoption and implementation of new technologies in Coast Guard operations. These considerations rest on sociological and cultural evaluations of the Coast Guard as a uniformed military entity dedicated to humanitarian and commercial assistance in times of peace and serving as an armed force in law enforcement and wartime circumstances. Clearly, the significance of the various roles shifts according to circumstances, and the command support for and openness of the command structure to change will vary according to internal structural features and external events. Each scenario, picturing very different event possibilities, will have an effect on the internal character of the Coast Guard. This, in turn, will affect its attitudes and openness to technological change. Considering this in reference to the various lead times that the technologies require for development and implementation, the role of the internal structure of the Coast Guard becomes highly significant in projecting future organizational states.

The third factor, mission weightings, is important in that the organizational features of the Coast Guard are dictated by its missions. Currently, the emphasis is centered on the protection of life and property and is embodied in the SAR function. If this were to shift markedly, the organizational features of the Coast Guard would necessarily change to the degree necessary to accomplish the new primary mission. In the case of ELT-Fisheries, it is possible that either more long range cutters or different patterns of cutter and/or aircraft use would result. Any change adds new vehicle capacity or inaugurates major tactical changes in the use of current vehicles creates pressures for organizational change.

* Synoptic Operations Patterning Analysis

These three factors will be the source of the various data bases utilized in SOPA modeling of the future organizational states of the Coast Guard. They will govern the input to each of the six short mini-scenarios and the longer description of empirical circumstances to be modeled.

There will likely be certain necessary adjustments in the Coast Guard's self image as mission shifts occur in the next 25 years. The current emphasis on rescue and assistance will gradually change to one of law enforcement. As a result, the public will change its perspective of the Coast Guard in a similar fashion; that is, it will see the Coast Guard as a police agency. This change will probably lead to both a growing sense of isolation among members of the Coast Guard, and a slow attrition of the public's image of the Coast Guard as the "good guys" and the replacement of this with a feeling that the Coast Guard are "cops".

B. Some Factors Governing Support for Technological Change within the Coast Guard

While three of the four factors involved in organizational modeling are considered in the body of this report (the character of the fleet mix, technological additions to the fleet, and mission analysis and weightings) the fourth factor, that of the role of the command structure of the Coast Guard in supporting or retarding technological change, remains to be discussed.

The Coast Guard, considered as a formal organization, possesses several structural features that determine, or at least constrain, its operational procedures. However, as in any formally organized agency, informal patterns of action parallel all of the formal rules and regulations and serve to either expedite or hold up decisions made on formal lines. This section will examine some of the sociological and psychological aspects of these formal and informal networks of relationships insofar as they influence the adoption of new technologies.

The major formal characteristics of the Coast Guard are:

1. its military structure of command and control,

2. the alternation of attitudes by generation in upper levels of command,

3. its dual function: a peacetime assistance role and a wartime combat support role.

Each of these formal features needs to be seen against several long-term social trends that operate throughout all three scenarios used in this report. The first of these involves the demographic and social characteristics of the United States population (as against the emphasis on world population dynamics discussed in the scenarios themselves). The second major social trend concerns the relative stabilization of the social class structure over the next 25 years after a period of major social change over the last 30 to 35 years. (See Figure VI-1). The period following the Second World War was marked by major social changes in the United States; large numbers of people were able to enter the ranks of the middle class through the opportunities offered by the GI Bill for education, housing, and business support. There was a marked upward mobility on the part of much of the population. More and more former members of the working classes became middle class in their economic and social circumstances. The late 1960's and early 1970's marked the end of this massive shift.

FIGURE VI-1

MAJOR SHIFT IN 1945 - 1975 PERIOD

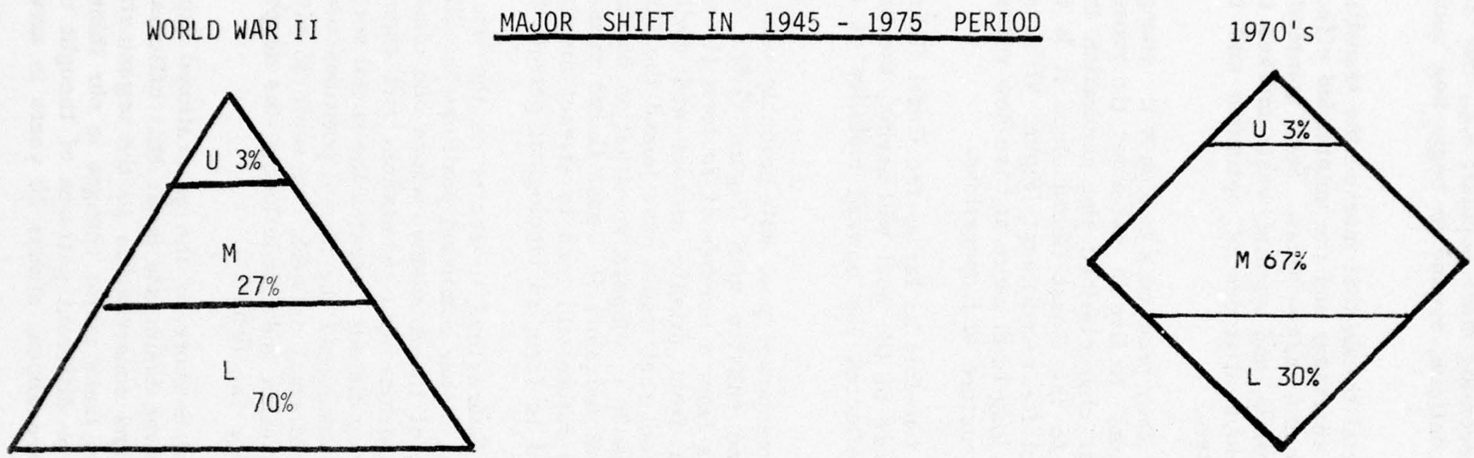
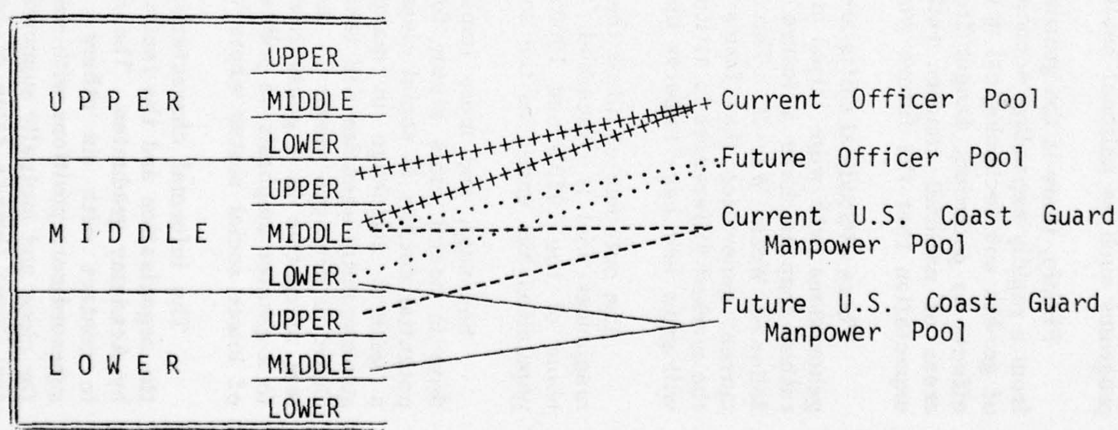


FIGURE VI-2

PROJECTED CLASS SHIFTS - U. S. COAST GUARD MANPOWER



The concern of many who had made these social and economic gains prior to the recent past shifted from upward mobility to the preservation of their gains. This conservative attitude tended to be reinforced by inflation beginning in the mid 1970's and reflected itself in various political attitudes becoming more popular; e.g., the "tax revolt" and the resistance of political leaders to continue, expand or begin new social programs such as national health insurance, etc.

Finally, there is the growing effect of the social trends that marked the transition from a rapidly expanding economy to one in which shortages and the unintended effects of growth and technological development have become major issues. Such unintended effects as pollution, danger from hazardous materials, and nuclear waste marked the areas of national concern rather than the previous attitudes of optimism and the expectation that the future would always be better.

These attitudinal shifts are important in that they produce a tendency in younger generations (who were raised in the era of expansion) to live in and enjoy the present rather than to have a future orientation such as characterized the generation that followed World War II. This is of importance to the Coast Guard since it is the current generation that forms the manpower pool for recruitment (Figure VI-2), and the marked differences in attitudes between older, long-term cadre and the new recruits will grow and have impacts upon Coast Guard structure and operations.

The outcome of all of these social trends is two-fold as far as the Coast Guard's manpower pool is concerned. First of all, the size of the pool will shrink, the baby boom of the 1950's and 1960's which in part reflected the upward mobility of the population has ended as the society stabilized.

Secondly, and more importantly, the new manpower pool will probably tend to drop in social class status for both officers and enlisted men (Figure VI-2). The potential decline in social class for recruits stems from a number of factors: (1) with a general shrinkage in manpower, competition from private sectors and civilian governmental agencies will take up most of the pool that would have joined the Coast Guard in previous years; (2) the military life in such a competitive situation becomes less attractive in a generation; and, (3) the predicted shift in Coast Guard missions to a greater emphasis on police-type duties in the future will tend to attract members of lower social status where these attitudes tend to form an ideological perspective.

The informal characteristics of the Coast Guard tend to center on the size of the organization and the fact that most, if not all, higher command positions are filled by Academy graduates. The common experience of the Academy, where one class is in contact with six others - in subordinate positions upon admission, and then in superordinate positions with respect to later entering classes - creates the social setting for close and mutually supporting friendships that transcend the formal positions within the Coast Guard's table of organization. This informal network can serve to either encourage or discourage change within the organization and can influence the adoption of new technologies and/or tactical procedures for the future.

More importantly, but tied to this informal network, is the generational aspect of Coast Guard command organization. Upper level commands insist that officers be career oriented. This supplies both continuity and conservatism to the organization. Since most of us cease to have the opportunity to make major changes in our thinking once we enter a career line, the impact of new or different patterns of thought tend to filter through a generational matrix; bosses are almost always 20 years in arrears of new junior management.

Figure VI-3 presents a schematic diagram of the attitudinal alternation of generations within the command structure of the Coast Guard as it affects the probability of accepting new technologies and/or tactical modifications in mission design. It must be stressed that certain political events might well override these basic attitudes; however, this tendency toward alternation of liberal and conservative attitudes toward change will underlie all command decisions, irrespective of the actual situation. Thus, a conservative commander may have to accept a new technology, such as LTAV, but his acceptance will be only minimal and will probably generate suspicion and uneasiness toward its use. In such circumstances, the tendency will be to find fault with the new technology rather than to consider its virtues of potentialities. In the case of "liberal" command periods, the reverse situation will apply in the assessment and use of new technologies and/or tactical applications - only in this instance with a liberal bias that emphasizes the technological virtues.

As far as this analysis is concerned, the major point is that the periods indicated in the diagram as potentially open for change are the periods when new technological and/or tactical approaches can most likely be introduced successfully. Thus, if analysis shows that adopting certain new vehicles is optimal to mission performance and that mission has real impact on Coast Guard operations, the time to introduce that change with maximal possibility of adoption may be calculated.

When considered in concert with the lead times needed to develop and accept a technology or organizational change, these factors permit the assessment and interpretation of the social features of technological change in the SOPA exercises reported below.

C. Application of the Six Variable Version of SOPA

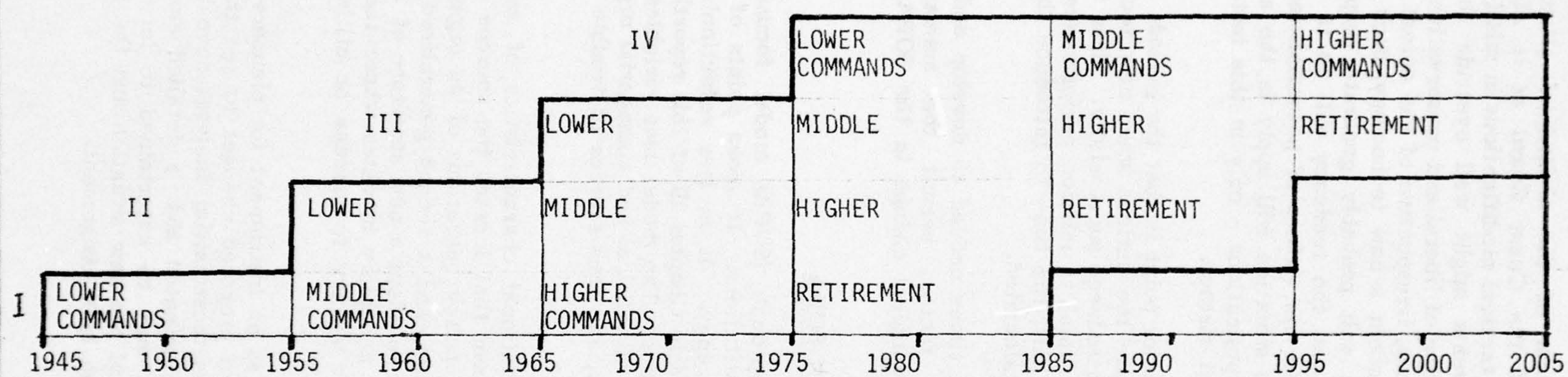
The Synoptic Operations Patterning Approach (SOPA) model focuses on the interaction between technology and social institutions. It seeks points of mismatch that create problems in introducing a technology. It is less reductionistic in its approach than the tree/matrix concepts (as used in Chapter III of this report) and more attuned to the organizational or social perspective. The model uses variables represent relational concepts linking technology to states of political and managerial organization. Scales serve to indicate good and poor matches, and thus sources of trouble for fitting a technology into an institutional base.

The SOPA model examines the organizational characteristics of an entity or agency in two forms: a detailed diagnostic form that locates the sources of existing or potential dysfunctions in the managerial or policy operations of an organization or of a technology embodied in an operative agency; and a second generalized form that analyses the initial capacity of an organization to adopt a new structure of technology, and locates the major area of reorganization necessary in cases where the projected changes exceed the existing capability of the agency to manage or utilize the new technology or task assignment.

The shorter version of the model serves as an instrument for planners and policy analysts to make a quick first-cut projection of proposed changes to see their effects on the structure of the agency involved. Once these initial analyses have been made, certain alternative courses of action can be eliminated and a detailed analysis along the lines of the diagnostic version of SOPA may be entertained to locate specific areas of mismatch between the requirements of the new situation and the capacity of the technology and/or agency to carry out the task assignment.

FIGURE VI-3

ATTITUDINAL CHARACTERISTICS OF THE COAST GUARD COMMAND STRUCTURE



	ATTITUDINAL	POTENTIAL FOR CHANGE
I	Conservative	
II	Liberal	Increased 1975 - 1985
III	Conservative	
IV	Liberal	Increased 1995 - 2005

In the short or generalized version, six future situations are considered (see Figure VI-4) with regard to two aspects: task requisites and organizational responses. Any task or job has certain minimal requirements in either technology management or both that need to be met in order for one task to be completed. The variables of task requisites seek to measure what these minimal needs are.

In similar fashion, organizational response variables measure the degree to which an agency meets the technological and managerial requirements of a task. Through the use of the scales developed for measurement of mission needs and the capacity of the Coast Guard to meet these needs, it is possible to estimate the degree to which the Coast Guard can expect to meet new situations. As noted above, the shorter version provides a gross measure of the degree of match or mismatch in a situation, a rough and ready way to eliminate certain alternatives or locate areas of real or potential dysfunction (mismatch) quickly.

The six variables that make up the generalized version of SOPA may be defined as follows:

The three task requisite variables measure the following features of a mission:

1. Size Variable concerns the dimensions of the problem in all of its many characteristics. It seeks to identify the size of the problem and outline what is needed to manipulate or deal with it.

2. The adaptability variable concerns the degree to which the problem needs to be modified in some way before it can be solved.

3. The space/time variable addresses the spatial spread and the time dimensions involved in solving the problem. Thus, in an SAR mission, the time factor is more important, but is conditioned by the distance the unit is located in relation to the emergency. In an MEP oil spill the spatial spread may be more important than the time needed for clean-up. There is a direct relationship between time and space for almost every problem; and it is this feature that is measured by this variable.

In similar fashion, the organizational response capability of the Coast Guard is measured by three related variables:

1. The unit variable, or the "package" of men and vehicles, etc., that respond to the problem. A typical package may be a search aircraft, a cutter, and a shore radio relay station in an SAR mission. This variable seeks to measure the capacity of the total package to meet the problem;

2. The program variable concerns the way in which the unit "packages" are managed in solving a problem, i.e., their tactical use;

3. The boundary variable addresses the effective limits of time and space involved in using the unit "package", i.e., the respective and combined ranges and speeds of the responding "package". Typical situations are described in the earlier mini-energy analyses above. (Chapter V).

In Appendix G the rationale for the choice of values of these variables for each of the six situations listed in Figure VI-4 is outlined.

FIGURE VI-4

SIX SITUATIONS ANALYZED

TIME	SCENARIO		
	X	Y	Z
1990	SITUATION 1	SITUATION 2	SITUATION 3
2005	SITUATION 4	SITUATION 5	SITUATION 6

The generalized version of the SOPA model is designed to quickly delineate major areas of potential problems in the organizational state of an enterprise by comparing its gross capacity to fulfill a mission and the mission itself. The mission is analyzed to clarify the tasks that are involved. The responses are either matched or mismatched to that situation. Mismatches are too low to meet task requirements indicate that either the task is too difficult for the agency or insufficient resources have been committed to the task. Conversely, mismatches with responses higher than task requisites indicate that the agency is capable of fulfilling the assigned missions, but not necessarily in a cost effective manner.

A second aspect of the model in this form is the first cut assessment of the internal consistency of an organizational format. The range of values internal to an organizational format is limited; mismatches between aspects of responses lead to internal dysfunctions in an enterprise.

Finally, there is an indication of the degree of change involved in the shift from one organizational state to another. Shifts that involve great changes in capacity to either much higher or much lower values indicate greater difficulty in making the changes needed than do shifts that are smaller in dimension.

With these factors in mind, the data summarized in Table VI-1 can be interpreted with respect to the major characteristics of the six situations discussed above. Limited space confines us to a brief discussion of the six situations.

An examination of Table VI-1 indicates that in all six situations and for both Case A (in which all of the technologies predicted in the technological forecast are operationally available) and Case B (in which the most likely fleet mix occurs), the values described for Organizational Response either match at least two of the variable codings for Task Requisites or overmatch them. This indicates that in all six situations the Coast Guard will be able to meet its obligations.

However, areas of mismatch also need to be noted to locate potential problems. These may be specified for each scenario condition:

1990X In Case A there is a marked increase in Coast Guard capacity; e.g., codings are at a level of 8 for all three variables, significantly higher than the values assigned to the task requisites for this period (codes of 6, 5, 6). This presents a problem for the Coast Guard at this time in that there is a very large increase in the sophistication and costs of operations of the newly adopted technologies.

It must be remembered that this excess capacity is found only in the circumstances described in this scenario at this time point. In the 1990 Y scenario, the organizational responses (using the same technologies as in 1990 X) fall somewhat short of the needs. Any mismatches that occur in these analyses are case specific; they are valid only for the circumstances described in the particular scenario being discussed.

In other words, the Coast Guard can do the job, but in this situation, the expense incurred in maintaining the complex fleet mix are far too high for what the scenario predicts will be needed.

There is less mismatch in Case B. The increased values for the Program and Boundary variables indicate increased intelligence gathering capacity, but the match between units and size shows that the fleet mix is adequate to meet predicted needs.

TABLE VI-1

SUMMARY OF VALUES FOR GENERALIZED SOPA ANALYSIS OF SCENARIO DATA

1. BASELINE: 1980

Task Requisite Variables		Organizational Response Variables	
Size	4	Unit	6
Adaptability	4	Program	7
Space/Time	6	Boundary	8

2. 1990 - SCENARIO X

Task Requisite Variables		Organizational Response Variables	Case A*	Case B*
Size	6	Unit	8	6
Adaptability	5	Program	8	7
Space/Time	6	Boundary	8	8

3. 1990 - SCENARIO Y

Task Requisite Variables		Organizational Response Variables	Case A*	Case B*
Size	9	Unit	8	8
Adaptability	7	Program	8	8
Space/Time	8	Boundary	8	8

4. 1990 - SCENARIO Z

Task Requisite Variables		Organizational Response Variables	Case A*	Case B*
Size	3	Unit	7	5
Adaptability	8	Program	7	8
Space/Time	5	Boundary	7	7

5. 2005 - SCENARIO X

Task Requisite Variables		Organizational Response Variables	Case A*	Case B*
Size	4	Unit	8	7
Adaptability	6	Program	8	8
Space/Time	7	Boundary	7	9

6. 2005 - SCENARIO Y

Task Requisite Variables		Organizational Response Variables	Case A*	Case B*
Size	4	Unit	9	9
Adaptability	5	Program	7	7
Space/Time	6	Boundary	8	8

7. 2005 - SCENARIO Z

Task Requisite Variables		Organizational Response Variables	Case A*	Case B*
Size	7	Unit	7	8
Adaptability	8	Program	7	8
Space/Time	8	Boundary	9	9

* Case A: All available vehicle technologies are assumed in use.
Case B: Most likely fleet mix (only replacement for over-age vehicles).

1990 Y: In both Case A and Case B there is a shortage of operational units (both code 8) to meet the needs indicated by the scenario, which codes at 9. This indicates that although the administrative and control mechanisms are adequate, as indicated by the Program and Boundary variables, the time lag involved in training and inclusion of new technologies into the fleet have not yet been overcome in either Case A or Case B.

1990 Z: The values assigned to the problems faced by a regionalized Coast Guard are lower than in the baseline scenario because each region's characteristic problems are smaller than those that would confront the Coast Guard if it still possessed its former degree of national responsibility. The mismatches between the size of the problem and the unit values for both Case A (coded 7) and Case B (coded 5) indicate that the fleet mix and vehicles available in 1990 for this scenario are too complex for the more narrowly defined regional responsibilities that the Coast Guard now has. Other mismatches between the Case A program variable (coded 8) and the adaptability variable (coded 7) and between the Boundary responses (coded 7 in both Case A and B) and the Space/Time variable (coded 5) illustrate the difficulties that are potentially present in managing a regionalized agency when the new technological developments in intelligence gathering and surveillance require complex interfaces. In all of these cases, the organizational response is higher than required by the job to be done. This means that the Coast Guard can certainly do the job, but that it is not doing so cost effectively.

2005 X: In both Case A and Case B the organizational responses are higher (except for the Boundary variable in Case A, which matches) than the coded values for the Task. Again the situation reflects the need to maintain a complex administrative, intelligence and control apparatus in the face of shifting problems that only partially reflect prior conditions. Efforts to adequately control environmental problems in an effective manner have led to the development of large administrative "tails". These cause the large mismatches between the Adaptability Variable (code 6) and the Program Variables in both cases (coded 8), or between the Space/Time variable (code 7) and the Boundary variable in Case B (code 9).

2005 Y: The highest degree of mismatch occurs in this scenario. The recurrence of peace leaves the Coast Guard with a highly sophisticated operational fleet (unit variables code 9 in both Case A and Case B) and an accompanying administrative organization that also codes above the task needs. These mismatches indicate a reluctance to remove the newest vehicles from the fleet, even though these are probably high performance vehicles designed for ELT and PSS roles in a war-terrorist threat situation and are only marginally useful in new situations.

2000 Z: The increased values in Task Requisites from 1990 Z (from 3 to 7 in size and 5 to 8 in Space/Time) are indicative of the rapid increase of problems occurring as coastal and sea-based industries become increasingly important. The increases in Coast Guard response variables also reflects: (1) the need to establish closer ties between the regionalized operational areas, and (2) the influence of the replacement of older units in the fleet with new, more specialized vehicles controled from regional headquarters.

In summary, the following conclusions may be reached in this first-cut application of the generalized version of the SOPA model:

1. in general, the Coast Guard should be able to meet all of the tasks it is assigned in the future.

2. With the exception of scenarios 1990 Z and 2000 Y, all of the scenarios show an increase in values for at least two variables, indicating a good probability that the situations that the Coast Guard will face in the future will themselves grow more complex. Even in the two scenarios noted, there are increases in one of the variables.

3. With the exception of 1990 Y and 1990 Z situations, and then only for one variable in each instance (Size-Unit-Case A and B for 1990 Y; and Adaptability-Program Case for 1990 Z), does the Coast Guard fail to match or overmatch the Task needs. In almost every instance, it possesses some degree of overorganization or redundancy in the system. This is neither an unusual nor necessarily undesirable condition in a military organization. The value of redundancy is that in emergency situations it is possible to perform regardless of potential losses; the tradeoff is that such a situation is not cost effective under normal conditions.

4. The tendency for higher codings to occur in the two variables that tend to indicate administrative and command/control functions (Program and Boundary) shows that much of the complexity of the Coast Guard's organizational format lies in these areas, rather than in operations.

D. Diagnostic Application of SOPA

While the generalized version of SOPA provides a first-cut picture of the ability of an organization to undertake a set of tasks as projected in a scenario, the resultant analysis is essentially limited to the problem of the overall viability of the organization to function in the described circumstances. The diagnostic version of SOPA is designed to locate those aspects of either the technology, the management of that technology, or the policy decisions involved in the adoption and operation of of that technology, which are actually or potentially dysfunctional.

The diagnostic version of SOPA has already been demonstrated in the analysis of the current organizational state of the Coast Guard as reported in the Interim Report. (Ref. 2). The same technique of analysis will be followed in the assessment of coded values for conditions described in the six mini-scenarios developed for the generalized version of SOPA and reported on above. In order to save space in this report however the justifications for the assignment of the coded values are not reported here. Only the tabulated results of the application of the scales reported in the Appendix of Ref. 2 are included here. These tables form the basis for the analysis that follows. As in the case of the generalized version of SOPA above, the analysis and discussion of the coded materials takes into account the probable command and control attitudinal features that are included in the preceeding analyses.

In the interpretation of the coded values, a number of basic assumptions need to be made clear. First, the technology codes are considered to be the same for all three scenarios since technology can be considered to develop as a function of time rather than discrete events. To be sure, certain events will hasten the R&D effort and force the quick adoption of technologies, but the technological forecast made in this study notes the earliest time period when a projected technology can be available no matter what the specified scenario circumstances. Secondly, the assigned codings are at best rough estimates; they are intended to indicate the most likely set of circumstances, not actual occurrences. Finally, although in the generalized version we were able to consider both the case of the total availability of technological developments and the most likely fleet mix, in this exercise, given more detailed level of analysis, we have restricted consideration to the most likely fleet mix.

Analysis and Interpretation: Technological Zone - 1990

As previously noted, the interpretation of the technological zone for all three scenarios for 1990 is the same. The Coast Guard is assumed to possess the same hardware by 1990 in all three cases. There will be significant differences in their use, but this is reflected in the interpretation of the managerial and political zones below.

As noted in the descriptive data for the mini-scenario above, the major changes available for Coast Guard utilization by 1990 include new MRS aircraft, SRR helicopters, 270-foot cutters and, more importantly, MTCS* and remote sensor devices, completed Loran C and Omega systems, and an operational GPS system. Fuel cells and supplies from oil shale will also be available.

The major change in adopting these potential technologies in 1990 from a baseline as described in Ref. 2 lies in the patrol mode rather than in the incident response mode. While remote sensors and advanced navigational aids serve to reduce the search aspects of SAR and ELT missions, as well as rapid location of oil spills, etc., in MEP missions, the actual interdiction and boarding of vessels remains approximately the same technologically. The major changes in coding are in the increases for all the values assigned to the technological zone variables in the patrol mode. (Man-artifact component variables code 4, 3, 4 in 1980; 5, 8, 6 in 1990; task component variables code 7, 5, 7 in 1980; 8, 8, 7 in 1990; and setting component variables code 7, 3, 4 in 1980 and 8, 8, 8 in 1990.)

This is indicative of the greater complexity of control over the circumstances of all phases of sea traffic that are permitted by the new sensor devices. This is especially reflected in the change in the setting component variables (coded 7, 3, 4 in 1980; 8, 8, 9 in 1990) where there is a dramatic difference in the values assigned to the locus of input and autonomy variables. Similar changes are recorded in the complexity of assemblage variable in the man-artifact component (coded 3 in 1980; 9 in 1990). All of these changes reflect the growing complexity of the applied technologies. Greater specialization in the surveillance and command mechanisms is becoming involved in the operational use of the fleet.

Analysis and Interpretation: Technological Zone 2005

Technologically, the period from 1990 to 2005 sees the rapid development of high performance vehicles (SES, SWATH, WIGES, Hydrofoils), effective LTAV, and various unmanned vehicles such as MTCS. New fuel sources are also available in a developed form. These continuing tendencies toward increased complexity and interactive dependency are reflected in the continued increase in values for the patrol modality in man-artifact variables, and in setting variables. Man-artifact component variables code 5, 8, 6 in 1990; 5, 8, 9 in 2005; setting component variables code 8, 8, 8, in 1990; and 9, 9, 9 in 2005. The general resistance to change reflected in the incident response aspect of technology, especially in the setting structure variable, codes 5 in 1980 and in 2005, reflects the unpredictability of an emergency, although the advanced means of surveillance and potential to react swiftly are increased, they still do not materially change the inability of the Coast Guard to effectively control a given situation by technological means alone.

* Maritime Traffic Control System.

In general, the period 1990-2005 sees technology increase in complexity and specialization. In general, the trend is toward the replacement of vehicular search by sensors and unmanned vehicles, and the continuing development of high performance vehicles to decrease the time needed to respond to an incident. Significant fuel savings are thus likely in the shift to remote sensors rather than vehicular patrol; but any savings made here would be used up by adopting high performance vehicles unless these were used in programs where their operations were optimized through close control of sea traffic and successful applications of navigational aids to significantly lower search time.

The interpretation of changes and potential dysfunctions in the Technological Zone occurs at two levels: (1) interpretations of the internal consistency of the coded values assigned at a particular period, i.e., 1990 or 2005; and (2) dysfunctions that may accrue in reaching this state from the values assigned for the baseline period. Table VI-2 shows that the incident response codes for 1980, 1990, and 2005 are nearly uniform. Thus, for the man-artifact variables, the codes are 8, 8, 8 in all three periods; the task component variables code 7, 7, 6 in 1980 and 7, 7, 7 in both 1990 and 2005; and the setting component variables, while varying to a greater degree, are still very similar -coding 4, 8, 7 in 1980; 5, 9, 8 in 1990; and 5, 9, 9 in 2005. As far as the patrol mode is concerned, the baseline period exhibits greater variance between component values, i.e., the man-artifact variables (coded 4, 3, 4) task variables (code 7, 5, 7), and setting variables (code 7, 3, 4), task variables (code 7, 5, 7), and setting variables (code 7, 3, 4), than do either the 1990 or 2005 periods. By 1990 and especially by 2005, the variance between component codes narrows considerably. The only area which retains a dysfunctional value is the setting structure variable in both 1990 and in 2005 - a situation reflecting the inability of technology alone to control all of the factors that are permitted into an area of action. Such factors as weather, political rights of others on the high seas, etc., are not ameniable to technological control.

The variance in the internal consistency of the technological zone in the 1980 baseline period reflects the wide range of vehicles in use by the Coast Guard. Many vessels of older age exist side by side with modern technologies. By 2005, indications are that the fleet will be more modern, consisting of fewer types, and these being closer in age and thus similar in maintenance and operational characteristics. Finally, the adoption of new non-vehicle technologies permits the reduction of both numbers and types in the fleet mix.

The size of the shifts in the variables noted above means that there will be significant differences required in operational procedures for the Coast Guard by 2005. This presents more of a managerial problem than one of technology per se.

Analysis and Interpretation: Managerial Organization

Managerially, the Coast Guard may be considered as generally well organized in the 1980 baseline period. The basic patterns of the 1990 X scenario are the same as in the baseline period, but with most of the values assigned at a higher level of coding. Thus, in 1980, the communications component variables code 7, 8, 7, while in 1990 they code 8, 9, 8. The variables for institutional domain code 9, 7, 7 in 1980 and 9, 8, 8 in 1990 X, and the codes for variables of legitimacy component code 7, 8, 8 in 1980 and 8, 8, 8 in 1990 X. These circumstances illustrate the changes that reflect the adoption of new and more complex technologies - making the intermediate command levels (District and Area Headquarters) more important in controlling operations through centralized intelligence centers and operational programming for patrol functions.

TABLE VI-2

SUMMARY TABULATION OF CODED VALUES FOR VARIABLES FOR SIX FUTURE SCENARIOS

VARIATIONS*	1980X	Baseline	1990 X		1990 Y		1990 Z		2005 X		2005 Y		2005 Z	
	P**	I	P	I	P	I	P	I	P	I	P	I	P	I
TECHNOLOGICAL ZONE														
Man-Artifact														
Locus of Dominance	4	8	5	8	5	3	5	8	8	8	8	8	8	8
Complexity of Assemblage	3	8	8	8	8	8	8	8	8	8	8	8	8	8
Phases of Unit Interaction	4	8	6	8	6	8	6	8	9	8	9	8	9	8
Task														
Serial Characteristic	7	7	8	7	8	7	8	7	8	7	8	7	8	7
Output Form	5	7	8	7	8	7	8	7	8	7	8	7	8	7
Throughput Form	7	6	7	7	7	7	7	8	7	8	7	8	8	7
Setting														
Setting Structure	7	4	8	5	8	5	8	5	9	5	9	5	9	5
Locus of Input	3	8	8	9	8	9	8	9	9	9	9	9	9	9
Autonomy	4	7	8	8	8	8	8	8	9	9	9	9	9	9

VARIATIONS*	1980X / Baseline	1990 X	1990 Y	1990 Z	2005 X	2005 Y	2005 Z
MANAGERIAL ZONE							
Communications							
Locus of Authority	7	8	9	7	8	7	7
Channels of Communication	8	9	9	9	9	9	9
Complexity of Linkage	7	8	9	9	8	8	7
Institutional Domain							
Agency Scale	9	9	9	8	9	9	8
Heterogeneity	7	8	9	7	8	8	9
Concentration	7	8	8	8	9	8	9
Legitimacy							
Boundary of Authority	7	8	9	6	8	7	6
Social Control	8	8	9	8	9	8	8
Locus of Validation	8	8	8	8	9	9	8
POLICY ZONE							
Communications							
Locus of Authority	8	8	9	7	9	8	7
Channels of Communication	9	9	9	9	9	9	9
Complexity of Linkage	7	7	8	7	9	9	8
Institutional Domain							
Agency Scale	9	9	9	8	9	9	8
Heterogeneity	8	9	9	7	9	9	8
Concentration	9	9	9	9	9	9	9
Legitimacy							
Boundary of Authority	6	8	9	5	9	7	5
Social Control	7	8	9	7	9	7	8
Locus of Validation	9	9	9	9	9	9	9

* For Definitions of Variables See Appendix

** P=Patrol I=Incident

The 1990 Y organizational format shows significantly greater values for almost all variables (only 2 variables do not increase; agency scale-already at a high level of 9, and locus of validation which remains at level 8, since it concerns ultimate legal responsibility) which are internally consistent, and reflects the very important increase in complexity and control that result from the external threat posed by the scenario. Not only is there a need to adapt to the requisites of new technology, there is a significant need to be able to respnd to terrorist and war threats. The organizational formats for management in 1990 Z are relatively poor; the large discrepancy between the communications component variables (code 7, 9, 9) and between the variables of the legitimacy component (code 6, 9, 9) indicate significant potential dysfunctions; decentralization in the face of technological requirements for centralization make this scenario one of the worst of the situations posed in the study. Significantly low codings at the locus of authority variable (code 7) and for the boundary of authority variable (code 6) reflect this decentralization and would be the locus of most dysfunctions in attempts to operate an effective Coast Guard effort under the prescribed conditions. The introduction of the new technologies, especially in the areas of remote sensing and intelligence, requires central control for the interpretation and optimal operational control of a smaller more sophisticated fleet. Decentralized control makes both of these objectives almost impossible.

By 2005, the Y scenario exhibits a reduction in coded values assigned in five of the variables (Locus of Authority 9 to 7, Complexity of Linkage 9 to 8, Heterogeneity 9 to 8, Boundary of Authority 9 to 7, and Social Control 9 to 8). In large measure, these reductions reflect the resolution of the war-terrorist problems of the 1990 period. The shrinkage of managerial complexity, however, creates problems, especially in the dramatic drops in the Locus of Authority and Boundary of Authority variables. As noted in Reference 2, the increased bureaucratic structure in Headquarters, where the intelligence data from remote sensors and unmanned vehicles would be processed, and limited resources for operational control in the field to make use of the data would cause potential problems. The notion that once complex control and command techniques and modern information gathering techniques are adopted, i.e., high technologies, they can be run by less complex field units is an error.

High technologies require complex maintenance and operational staffs, and it is these very areas which are reduced in the scenario.

A similar problem occurs in 2005 where complexity of Linkage falls from a 1990 value of 9 to 7. However, increases in 2005 Z over the 1990 Z values in Heterogeneity, and concentration help dampen its overall effect.

In 2005 Y, the Coast Guard is reduced in size and budget. This will mean that it can only operate at less than optimal levels if the cuts are too severe with respect to the complexity of the war time organization set up in the 1990's. In the case of 2005 Z, the attempt to use high technology in a decentralized manner has similar consequences.

The 2005 X scenario is internally consistent and capable of operationally controlling the new technologies.

Analysis and Interpretation: Policy Organization

A pattern similar to that in the Managerial Zone emerges with the codings of the policy area. Again the values for both the 1990 X and 2005 X scenarios reflect greater internal consistency than in the 1980 baseline situation. In 1990 X Complexity of Linkage (code 7) still remains a problem, but the values of the Heterogeneity, Boundary of Authority, and Social Control variables all rise to make the values more internally consistent. This is especially true of the Boundary of Authority variable where the increase in value is dramatic, from 6 to 8. The increased role of the Coast Guard in a period of environmental concern thus leads to an increased policy role because the Coast guard has both the expertise and the powers of enforcement. This will also make policy cooperation with such agencies as NOAA, EPA and others a major factor in meeting MEP mission needs.

The consistently high values assigned to the 1990 Y policy variables reflect a consistent, determined policy to provide all that is necessary in order to allow the Coast Guard to perform its duties in a war-terrorist situation.

In both 1990 Z and 2005 Z, there are lower code levels assigned than in the base line area in several variables. Thus, in 1990 Z, Locus of Communications, Agency Scale, Heterogeneity, and Boundary of Authority all drop one level. The same is true for Locus of Authority, Agency Scale and Boundary of Authority in the 2005 Z assignments. Indeed, the low code level of 5 for the Boundary of Authority variable in both is so low as to indicate that there is no real policy regarding Coast Guard operations in a decentralized situation. With the very severe limitations on areas of jurisdiction that this value implies, real decision and policy making power lie outside of the Coast Guard itself.

Thus, the conclusion arises that unless conditions are such that the situation demands policy decisions (as in the 1990 Y scenario with severe external threats) the tendencies noted in the analysis of the baseline data of policy drift and vulnerability for the Coast Guard will probably be accentuated. The tendency toward decentralization in authority in concert with growing technological complexity creates the major organizational problem for the future of the Coast Guard.

Conclusions

Several conclusions may be drawn from this analysis, although some of the managerial and policy organizational formats are linked to scenario conditions. Certain features of all scenarios can be seen as important for the Coast Guard irrespective of specified conditions.

The initial finding for this diagnostic application of SOPA to the future projections made in this study is that in all cases technological developments will continue to grow more complex. In general, most future technologies projected for the Coast Guard tend to stress two basic features: (1) reduction of manpower needed to operate the technology, and (2) improvement of performance for particular vehicles. The first of these is essentially energy reducing in nature; the latter is almost always energy consuming. Whether the two balance is dictated by the extent to which the former are applied as against the numbers of the latter technologies that are adopted.

It is important to note that although the adoption of such technologies as remote sensors and satellite positioning systems reduces the operational energy utilization by reducing the numbers of vehicles and men utilized in patrol modalities, there is a higher energy cost in the maintenance and manpower loadings needed to train for and service the new technologies. In similar fashion substitution of simulators for training exercises with vehicles (which utilize up to 35% of a vehicles use) also have hidden maintenance and operating costs.

Of greater importance, however, is the tendency to have almost geometric managerial and policy growth while the rate of technological change is arithmetical. In other words, every advance in energy savings at the operational level is probably more than used up in the new and necessary headquarters functions that such technologies require for their optimal utilization. Greater amounts of information, the product of most of the new technologies, require ever greater and more complex command and control mechansims for their use. High performance vehicles require accurate target fixes to justify their relatively short ranges, most do not have the fuel capacity to engage in long-term operations. The technological future of the Coast Guard appears to be one of increasing reaction capacity with a limited number of vehicles through the use of high performance vehicles directed by a more complex intelligence structure that locates and targets vehicles more accurately. In use, the energy savings that this apparent rationalization accomplishes in the operational aspects of the Coast Guard may cost more (in both energy and fiscal terms) in the managerial aspects of Coast Guard missions.

A danger that shows up in all potential futures except the surprise free situation is that there will be serious mismatches between actual Coast Guard managerial and policy behaviors and the requirements needed for the optimal utilization of the projected technological changes. In short, the Coast Guard and/or DOT will attempt to inaugurate the technological changes noted above without making adequate provision for the command and control organizations needed to operate them effectively, e.g., in the 1990 Z and 2005 Z scenarios. As noted above the Coast Guard will have sufficient redundancy in its structure to handle all of the problems that the scenarios project. However, the most likely solution that the Coast Guard will adopt to managing the new technologies will be to extend the current managerial structure. It does not follow that this is the best operational nor the most cost effective manner to deal with the problems that will be forthcoming. Depending on the outcome of an analysis of new tactical possibilities for vehicle control and command growing out of the adoption of new technologies, it is possible that managerial formats very different from the current bureaucratic structure may serve the needs of the Coast Guard in a more cost effective fashion. The experience of NASA in controlling high technologies through task forces rather than the usual line and staff approach is a case in point.

The consistent tendency of the model to predict dysfunctions in the areas of allocation of authority in all scenario conditions of the future (barring the war situation) indicates that this is a major potential source of future problems in the Coast Guard. Failure to provide sufficient managerial structure will only mean that there will be increased ineffectiveness whenever a new technology is introduced. There can be no effective substitution of a technology for either a managerial or a policy making role; all three components are required for any of them to work. The overall American cultural tendency to seek technological solutions for problems that are essentially managerial or political tends to make the problem worse. Current energy policy is a

case in point. While technology can provide some changes in energy use, real energy savings require other solutions. For the Coast Guard, as a case in point, policy decisions to restrict certain types of missions or eliminate them altogether (such as legalizing certain drugs and eliminating costly and futile ELT missions) would do more than many suggested technological changes to cut fuel use. It is also a truism that political changes of the type mentioned have little chance of enactment.

A third potential danger for the Coast Guard then will be that an organization currently designed for humanitarian purposes will more and more become a police oriented agency. As energy supplies become short, and hard policy decisions are avoided, regulatory agencies will tend to become buffer units used by political entities to absorb public criticism. Such an infringement into the technical operations of a highly skilled agency can only make managerial problems more difficult. At best it will discourage and frustrate the professionals who seek to carry out mandated tasks; at worst it will make the agency completely ineffective and a political arena for favoritism. Such conditions are not unknown in history. The English armed forces suffered from the sale of officer commissions into the 20th century. In an era of ever-growing technological change and complexity, the need for regulatory functions becomes increasingly important. Consequently, the potential dangers from political interference produces a growing vulnerability for the Coast Guard.

REFERENCES

1. J. Fried and P. Molnar, "Organizational Patterning Analysis: An Instrument for Structuring Complex Systems" in Management Handbook for Public Administrators, J. Sutherland (ed.), New York: Van Nostrand, 1978.
2. Nero & Associates, "Technology Assessment of Low Energy Vehicles", Interim Report, prepared for the U.S. Coast Guard, November, 1978.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

1. Missicns

a. Our Coast Guard workshop in November, 1978, ranked the current leading missions in the following order of importance: (1) SAR, (2) ELT, (3) MEP, (4) CVS. Future mission rankings depend on the scenario assumed. With our three scenarios X, Y, and Z, the top-ranked missions in 2000 become MEP, PSS, and ELT, respectively. The composite ranking of top missions for that year becomes (1) ELT, (2) PSS, (3) MEP, and (4) SAR. (p. 36).

b. Underwater safety and security (USS) may become a significant new mission by 2005. Responsibilities would include rescue of underwater recreationists, servicing of underwater research habitats, patrol of nuclear waste storage sites, and possibly some ASW work. (p. 23 and Appendix A, pp. A-6, A-12).

c. With regard to ELT, it must be noted that "threats", such as smugglers or terrorists, may well use advanced, high performance vehicles and certainly recognize no energy constraints in the performance of their missions. (Appendix A).

d. The helicopter, the cutter, the patrol boat, and the ports and waterways boat will remain top priority vehicle types throughout the next 25 years. This is true even over a range of scenario assumptions and time span with broad shifts in numbers and kinds of incidents to which the service must respond. The currently available Cessna-type small fixed-wing aircraft and the new LTAV are also top ranking vehicle types during this period. Certain advanced-design surface vehicles, particularly the SWATH ship and the hydrofoil, will have high utility rankings as well. On the other hand, the presently important fixed-wing aricraft types (LRS and MRS) will decline somewhat in ranking. (p. 62, 64).

e. Basic Coast Guard activities may be categorized as patrol operations, incident response operations, and routine operations other than patrol. Patrol operations generally provide the logistical base for incident response. The multimission concept in single vehicle design will begin to break down as the incident response requirements of the various operating programs become more complex. The needed capabilities for incident response may exceed what can be built into a single patrol vehicle. Thus, the desirability of multimission patrols may decline, even though the multimission approach makes sense from an energy conservation point of view. (pp. 49, 51).

For example, with remote electronic sensing methods (e.g., satellite GPS, or Compass Cope type) can be adapted to Coast Guard operations, the multimission WHEC or WMEC patrols become less significant and single mission, dedicated high performance response vehicles increase in importance (e.g., hydrofoils and surface-effect ships dedicated to ELT). (pp. 67, 45, and 53).

f. With regard to new vehicle possibilities, we must keep in mind the constraint that 60% to 70% of the current Coast Guard fleet will still be operational in 1990, 25% to 60% in 2000. These estimates underscore the importance of tactics and component improvements to effect energy savings. (p. 40 and Appendix C).

g. Significant advances in technological sophistication of vehicles used for illegal or hostile purposes are to be expected. These will require a corresponding increase in the Coast Guard's technological capability to respond to ELT incidents and national emergencies. But, assuming that the Coast Guard keeps abreast of ongoing technological advances, total Coast Guard fleet mix requirements do not appear critically sensitive to a broad spectrum of variations in threat, e.g., a sharp increase in the number of ELT incidents. (p. 66).

h. Certain new vehicle-use ideas involve new tactical approaches as well. One possibility, not extensively explored in this study, is the mothership, i.e., a large floating living facility and operations base which could provide a means of reducing both patrol and incident response vessel weight by absorbing many of the life-support functions. The utilization of such a vehicle, however, must be judiciously planned since any centralized facility becomes more vulnerable from a military operations perspective. (p. 91).

2. Technological Opportunities

a. Numerous advanced and new technologies will become available over the next 25 years. However, the Coast Guard will have little, if any, direct influence over their development potential, date of availability, and salient performance characteristics. (p. 109).

b. In view of conclusion 1f, new subsystems as well as improved tactics and maintenance should be considered for the large fraction of "older" vehicles still in the inventory until at least 1990. However, budget limitations may inhibit installation of new components. (pp. 70, 72).

c. Improved design of vehicle power plants and engine components, e.g., mixers and blade shapes, can increase energy efficiency as much as 20% to 30% in new vehicles, 4% to 8% in existing ones. (pp. 83, 91, 108).

d. Diesel engines available currently or in the near future are unlikely to produce significant gains in energy efficiency. Gas turbines can produce major energy savings, but they introduce problems in a marine environment. However, design changes and improved energy efficiencies of the future gas turbines warrant their consideration for research and development support. (pp. 83, 97).

e. Advanced vehicles are typically high performance vehicles and, except for the LTAV, do not by themselves produce significant energy savings. However, when used in a context of different tactical approaches and/or advanced electronic surveillance techniques, their net effect can yield lower overall fuel consumption. (pp. 111, 178).

f. In view of a significant non-U.S.C.G. impetus for technological improvements, future aircraft are likely to produce more energy saving opportunities than marine vehicles primarily because the market demand for air vehicles is high (and expected to remain high). (p. 91).

g. The Coast Guard should pursue research on remote sensing and unmanned surveillance systems, inasmuch as they promise substantial long-term energy savings. At the same time one must anticipate an inherent resistance to the adoption of such methods, as they represent radical changes in current operational procedures. The organizational tendency toward "discounting the future" might be overcome in part by the introduction of life-cycle costing approaches. (pp. 97, 103).

h. Major improvements in propulsion transmission systems for cutters are likely. These will primarily result in weight savings, which, in turn, yield energy savings. (p. 95).

i. Fuel cells seem particularly attractive for use on cutters, especially in a "total energy system" context. Such systems involve the modification of existing systems, e.g., the space heating system, as well as the installation of fuel cells. (Appendix E).

j. Photovoltaic cells should be available in commercial quantities in the next 25 years. They are particularly useful as power supplies for buoys, reducing the frequency of service and hence, producing energy savings. However, a more urgent problem is buoy design and improvement, including the multimission buoy, (e.g., NOAA and Coast Guard needs) and self-monitoring of buoy equipment (e.g., via satellite communications). (pp. 75, 103, 109).

3. Energy Tradeoffs

a. The Coast Guard should investigate the possibility of adapting existing flight-path optimization systems to use by surface vessels. It is possible that substantial energy savings may be achieved improving the vessel capacity to adjust to sea state, weather, ocean currents, etc. This suggests the development of a mission planner's "slide rule" similar to the automated systems now employed by major airlines. (p. 181).

b. The Coast Guard does not now maintain an energy audit of the major existing vehicles, e.g., the top five vehicles in the relevance analysis. An energy audit consists of a detailed determination of the patterns of energy consumption for a vehicle. Such an audit is needed for monitoring ongoing activities and for making energy-aware decisions about future vehicle improvements and acquisitions. (p. 111).

c. The Coast Guard should seriously consider insuring reasonable continuity and stability of its future energy supplies by the consumption of dedicated energy facilities to produce synthetic crude for diesel and jet fuel from coal and oil shale. With currently rising prices of fuels derived from natural crude oil and much of current interest in the rapid development of synthetic fuels (cf. Carter's energy speech, July 15, 1979), further investigation of this possibility appears very worthwhile. (p. 110).

d. Energy analysis of individual vehicles indicates no dominance of a single superior vehicle in terms of transport efficiency <u>and</u> specific energy. Rather, the attractiveness of a vehicle is a function of performance parameters, such as speed, and design parameters, such as Froude number. (pp. 116, 178, 181).

e. Coast Guard vehicles appear to be at least as energy efficient (and in some cases more so) than their civilian counterparts. (p. 129).

f. The energy analysis indicates:

(1) If energy conservation is the objective, the energy-minimizing vehicle choices are preferred to the response-time-minimizing vehicle choices for SAR rescue, SAR search, ELT fisheries, ELT smuggling, MEP oil spill, aircraft patrol and ship patrol, i.e., for all missions considered in the energy analysis. (pp. 178, 181).

(2) If response time minimization is the objective, the response-time minimizing vehicle choices are preferred to the energy-minimizing vehicle choices for the same mission. (pp. 178, 181).

g. On the basis of the mission scenarios considered in the Level-3 energy analysis, existing vehicles are almost always the best vehicles in terms of energy consumption while the new/advanced vheicles are almost always the best vehicles in terms of response time. (p. 178).

h. The energy analysis of alternative liquid fuels derived from oil shale and coal indicates that the oil-shale-based supply system has a marginal advantage over the coal-based supply system. (p. 132).

4. <u>Organizational Aspects</u>

a. Numerous advanced and new technologies will become available over the next 25 years. However, the Coast Guard will have little, if any, direct influence over their development potential, date of availability and salient performance characteristics. Most of the related Research and Development effort will be devoted to the needs of the other armed forces, particularly the Navy. (pp. 69, 90).

b. Significant savings in energy can also be obtained by actions not directly connected with vehicles such as:

(1) Re-examination and simplification of administrative procedures and operations; (pp. 97, 111).

(2) reduction of onshore facilities and operations (accounting for 30% to 35% of the energy used by the Coast Guard). (p. 104).

c. In all situations represented by the scenarios, the Coast Guard will have the organizational capacity to meet the needs of the situation; albeit at higher cost in the "administrative tail". Technology, while contributing to a reduction in operational manpower requirements, creates new manpower support needs, e.g., mission optimization, analysis of surveillance data, and maintenance of complex equipment. (pp. 204, 205).

d. Increased technological complexity and sophistication will pose new challenges to Coast Guard management. In any complex system where virtually "everything interacts with everything", simple expansion or centralization of the current managerial structure is not the best management approach. Rather, more sophistication is indicated. This raises a new concern: the resulting administrative and logistic energy expenditures, generally hidden and indirect, may negate operational energy savings. (p. 211).

e. Greater cooperation and coordination with NOAA, EPA, and other agencies is anticipated. (p. 210).

f. A change in top mission priority, from SAR to ELT, is likely to alter the Coast Guard image from that of a humanitarian rescue service to a police force. Such a shift poses potential problems in personnel morale, attitude, and loyalty. (p. 212).

B. Recommendations

Recommendations relating to energy savings which may be drawn from the above findings are as follows:

1. Reduce the Coast Guard's fuel dependence by examining the feasibility of a three-pronged strategy to develop its own fuel supply:

(a) Eastern and Southeastern districts (about 50% of Coast Guard fuel use) - construct a small complex to produce synthetic fuels derived from Appalachian coal, with about 5,000 barrels per day capacity.

(b) Midwest and Western districts (about 25% of fuel use) - construct an oil shale plant in Colorado or Utah, possibly jointly with the U.S. Navy at the Naval oil shale reserves in Colorado.

(c) Alaska (about 17% of fuel use) - construct a small oil refinery in Alaska to supply Coast Guard needs in that area using Alaskan crude.

This strategy leaves only Hawaii (about 8% of fuel use) dependent on remote fuel.

We recognize that this strategy is unconventional (at least in the Coast Guard context) and expensive. However, the growing responsibilities of the Coast Guard with respect to ELT over the next 25 years make the analysis of such a concept a prudent undertaking at this time.

2. Examine the concept of a Total Energy System (TES)

This term refers to systems that utilize energy production in a most efficient way. Generally, a TES is dedicated to produce a principal energy from, say electricity, and to utilize the by-products (e.g., waste heat resulting from electricity generation) to perform other relevant functions. A test of particular significance to the Coast Guard involves the use of fuel cells, which can be installed on Coast Guard cutters and on-shore facilities to produce electricity. The waste-heat provides energy for space-heat and water for on-board use. Waste heat from Diesel and gas turbine engines on-board Coast Guard vehicles is the basis for another promising TES.

The TES concept was not fully explored in this project because it requires a detailed understanding of the energy use patterns aboard cutters and at shore facilities. With systems such as fuel cells, solar photovoltaics, solar heaters, and co-generation concepts becoming available in the future, the application of TES concepts for Coast Guard vehicles and facilities becomes possible and merits detailed investigation.

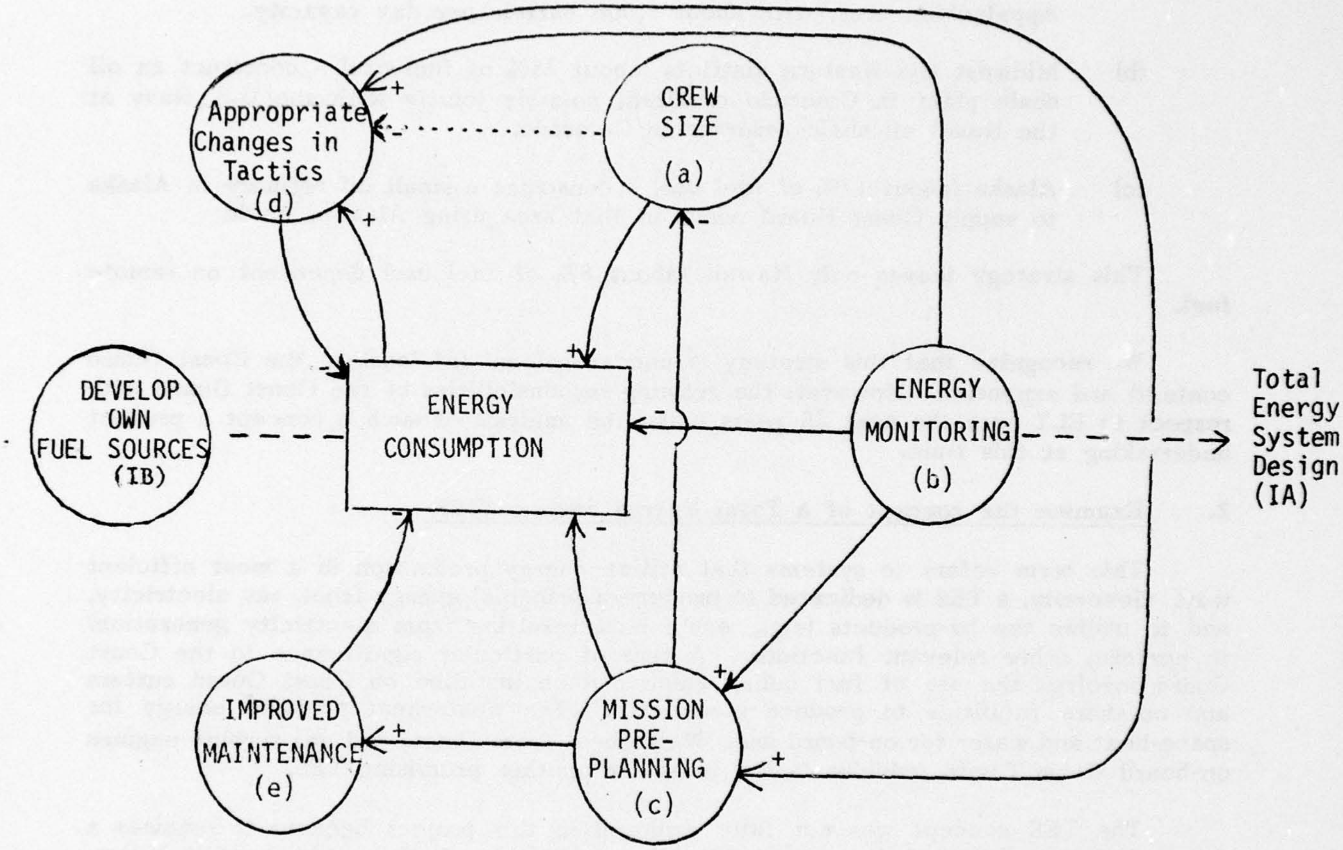
3. Reevaluate tactical operations

There are at least five aspects which merit consideration: (a) crew size reduction; (b) energy monitoring procedures; (c) preplanning of missions; (d) changes in tactics; (e) vehicle maintenance procedures.

These are clearly related as shown in Figure VII-1 and should thus be considered together.

FIGURE VII-1

ENERGY SAVING TACTICS AND THEIR IMPACTS



Legend

+ impact reinforcing or supporting (increase leads to increase, decrease leads to decrease).

\- impact counteracting (increase leads to decrease, decrease leads to increase).

(e) refers to item in this section

..> impact only applies to reduction (in crew size), not to increase (in crew size).

--> impacts on non-tactical (stragegic) energy saving concepts.

For example, the more energy monitoring is done, the more mission preplanning is possible. The lower the crew size, the less energy consumption occurs in a given vehicle mission. We therefore feel that they should be considered together as an energy saving program.

(a) Crew Size Reduction

The more personnel there are onboard a vehicle, the more space, supplies, and life support equipment is needed and the more energy is used. Some lessons can be learned from the U.S. space program, e.g., regarding the minimization of weight in manned space vehicles. Increased use of simulators, preplanning of missions, automated fault detection systems, and modular design all contribute to crew size reduction. The first task is to determine whether sufficient energy savings can be effected by crew size reduction. This will require an energy audit of several ships and their operation. First, the "normal" operation is analyzed, then reductions in crew and their impacts are considered. Next, the resulting energy figures are compared with allowance for residual uncertainties. If significant energy savings can be expected through crew size reduction, an initial evaluation of necessary or desirable contributing procedures, such as use of simulators, should be undertaken.

(b) Energy Monitoring Procedures

The energy shortage is a relatively new problem; therefore, it is not surprising that the available information on energy use in the Coast Guard is inadequate for current management needs, especially for estimating the energy expended in any one Coast Guard mission. Improvement in energy savings is predicated on an improvement in the energy data base. Neither the Abstract of Operations nor other available Coast Guard documentation is sufficient; however, the current activities of the Coast Guard involving development of Energy Management Information System appears to be a significant first step in this direction.

Specifically, the Coast Guard should:

(1) Formulate an energy auditing/accounting system which depicts the energy balance for major Coast Guard operations and missions;

(2) identify the categories for collecting information, based on the evaluation of the energy auditing/accounting system;

(3) monitor short - and long - term trends in each of the information categories through an evaluation of forecasts which may be developed in-house or by others, e.g., DOE, oil companies, CIA, and think tanks. A computerized "ship's log" which integrates and stores energy data on magnetic tape, analogous to a flight recorder, is also a possibility. Data thus sorted could be transferred to shore-based computer facilities for subsequent use.

(4) develop energy flow networks for depicting energy consumption and supply for major Coast Guard activities and missions;

(5) analyze and interpret the information to develop the basis for estimating future energy requirements of the Coast Guard.

The resulting energy information system structure was suggested in section IV-E-3.

(c) Preplanning Missions

Computerized flight path optimization is a standard airline procedure prior to take off and results in significant fuel savings. Airline figures suggest 15% saving per revenue-passenger mile over the past seven years. Preplanning is feasible in many cases, but particularly in missions involving patrol, surveillance, search, mapping, and navigation aids maintenance.

Examples:

(1) More sophisticated maintenance scheduling techniques for buoy tending operations (AN), geared to a reduction in transit time or distance traveled per buoy;

(2) patrol route analysis: aircraft versus ship, rendezvous versus fixed pattern;

(3) feasibility of a simple mission planning calculator or slide rule for use by Coast Guard ship officers.

The use of a program such as JETPLAN by the Coast Guard is a step in this direction.

d. Changes in Tactics

Tradeoffs must be sought between response time and energy consumption, since it is rarely possible to find a vehicle which is best from both energy and response time considerations.

Tradeoff problems will become more severe in 1990 than in 1980. Nearly all new vehicles available in the next fifteen years will reduce response time rather than save energy.

(e) Improved Maintenance

Improved vehicle maintenance is the quickest, easiest-to-use means to effect energy savings. The Coast Guard may be able to achieve a 5% to 15% energy savings per vehicle solely through improved maintenance. Clearly, this approach requires development of new maintenance procedures.

4. Reevaluate Organization and Training

Changes in organization and training needs are inherent in the preceding recommendations.

Development of a total energy system and Coast Guard fuel sources require not merely new multidisciplinary engineering capabilities but also innovative management. Energy monitoring, mission preplanning and maintenance changes also suggest new management skills and training requirements.

We anticipate a marked increase in the application of non-vehicular innovations, especially in the area of electronic information gathering and processing, i.e., sensors, long range navigation aids, satellite and unmanned drone aircraft in surveillance and intelligence activities. Given this expectation, certain major organizational and training changes may be needed to make the utilization of such non-vehicular technologies both operationally and cost effective. These effects will impact upon three areas: (1) the reduction of on-shore facilities and operations; (2) administrative procedures; and (3) training of personnel.

(a) Reduction of On-shore Facilities and Operations

The adoption of non-vehicular technologies (sensor, satellites, etc.) means that wide areas of coast and inland waterways can be monitored for pollution and (with the requirement of transponders) illegal traffic from a centralized intelligence center. Here electronic data can be translated into plots. Response teams may then intercept and/or respond as needed. The patrol effort now used would be greatly reduced. Combined with the operational analysis proposed in recommendation 3, the location and manning requirements of the current on-shore establishment may be rationalized, and probably reduced to save energy.

(b) Administrative Procedures

If centralized intelligence centers are adopted, then new administrative procedures for control and command may also be needed. It is possible that an operational analysis of events by mission, accompanied by the projected changes in mission weightings, may make current district boundaries obsolete. A certain amount of flexibility is possible within a military organizational format. The task concept, for example, evolved out of military necessity, and fit well into the more traditional line-and-staff structure that characterized military organizations. When tied to an operational mission analysis for the major areas of Coast Guard responsibility, administrative flexibility may well lead to administrative changes that may in turn yield energy savings.

(c) Training of Personnel

The materials presented in this report indicate the possibility of significant energy savings in the area of training. Althogh training is needed, and on-hands use of actual equipment must be part of the training effort, many aspects of training can be accomplished in other ways. For example, simulators can be effective training tools.

Simulated exercises require less energy than the equivalent exercises performed aboard ships or aircraft. In this connection, we note that the Coast Guard has begun to develop cutter, boat, and aircraft simulator plans.

Further, some 40% of aircraft utilization in the Coast Guard is reserved for training. There is ample evidence that most aircraft procedures can be simulated, saving considerable energy. Many ship-board activities can also be simulated.

Finally, with the emergence of new technologies and changes in mission weightings, there will be a consequent shift in the different skills needed by the Coast Guard. For example, given the high probability that MEP missions will increase in importance, it will be necessary for the Coast Guard to consider adding training in ecological effects, clean-up of pollution, etc. to its various courses for both academy students and enlisted personnel. These shifts in training needs must be viewed in the light of expected personnel problems. Among these are the following. As the relative importance of Coast Guard missions shift, the public's perception of the Coast Guard will change, resulting in changes in the recruiting base. As technological complexity increases and the manpower pool both shrinks and falls in quality, changes in training (and operational) stability, e.g., on-shore rather than on-board locations for more areas of service, may help alleviate the loss of qualified personnel. Centralization of a number of functions may reduce the need to move personnel from station to station, yielding both morale and energy benefits.

This discussion suffices to express the importance of assessing the evolution of organization and training needed to avoid a mismatch between energy-saving technologies and their implementation. A holistic, rather than piecemeal, approach is vital.

5. New Vehicles

The LTAV is the one new vehicle which is directly energy saving. The Cessna-type aircraft is also highly desirable, but need not be one of new design. Both should be strongly supported.

A comprehensive, systematic, comparative evaluation of the LTAV concept is essential to determine its role. Such an evaluation should:

(a) Compare the LTAV concept with existing and new/advanced vehicles in the context of Coast Guard missions and needs.

(b) Consider all relevant dimensions that can and will affect the decision to design and deploy the LTAV concept. The dimensions of particular significance are: design and operational characteristics, expressed in terms of performance capability; economic, including capital as well as operational and maintenance cost; and energy intensiveness expressed as energy requirements - total and normalized with respect to performance capability.

(c) Explicitly consider the uncertainties that can significantly affect the results of comparative evaluation and the decisions to acquire the LTAV. Among the uncertainties of principal significance are: weather conditions, for example, wind speed, visibility, sea state; economic, for example, escalation in construction costs; and energy price and availability.

(d) Quantitatively determine the potential and viability of the LTAV concept, considering the above three aspects. For instance, it is essential to know how the uncertainties delineated above can affect the decision to deploy LTAV for Coast Guard use.

6. Monitor Research and Development

(a) Support and capitalize on the use of certain energy minimizing technologies as they become available for vehicles and to the extent they are deemed cost-effective. During the next 10 to 15 years, the Coast Guard will decide to acquire additional air and marine vehicles. Reduction in the energy requirements of these vehicles will occur primarily through improved/advanced engines, e.g., gas turbines for marine vehicles, regenerative engines for aircraft; weight reduction, use of new structural materials such as advanced composites for aircraft structures; automation in maintenance procedures, and the use of supercritical technology.

(b) Follow closely the development of remote sensing and unmanned electronic surveillance systems, including satellites, Compass-Cope type systems, etc.

7. Improve AN Equipment Life

The AN mission consumes so much energy in doing periodic maintenance that longer life equipment would pay large dividends in energy savings. The use of photovoltaic cells as power supplies and improved construction materials should be investigated.

8. Other Recommendations

Finally, there are three points not specifically aimed at energy savings which should be noted:

(a) Clarify the Coast Guard role in underwater safety and security as a new mission;

(b) examine the feasibility of a new category of officers to deal with environmental management; and

(c) do not minimize the value of high performance vehicles that appear to increase energy consumption. These vehicles are needed for high performance "threats" and may provide indirect energy savings.

APPENDIX A
External Events

1. Some External Events Affecting the Coast Guard - Indirect Impacts

The following potential events, either of a global scope or global impact, may have an important - albeit indirect - effect upon the operations, equipment, and organization of the Coast Guard.

Emergence of a Maritime Economy

The marine environment emerges as a major "economy" in its own right. Offshore energy production facilities, increased tourism, and an expansion of maricultural activities, for example, transform the commercial and industrial role of the world's oceans.

Global Climate Change

Although experts disagree whether the climate is becoming warmer or colder, any change will have profound effects.

Collapse of Agriculture

In many areas of the world, the level of agricultural production collapses.

Collapse of Natural Resource Base

In many parts of the world and for many critical natural resources, the known and readily accessible sources become economically and/or physically exhausted. A water shortage is a prime example.

New Resource Discoveries

New natural resource deposits are opened primarily in offshore areas and in the underdeveloped world.

Possession and Use of Mass Destruction Devices by Terrorists

Given continued nuclear proliferation, a terrorist group detonates a nuclear bomb, either having stolen or built it. This creates an international emergency of the first order.

Recreational Vehicles Used as Weapons Platforms

Terrorist or government use of recreational vehicles and equipment as weapons and weapons platforms becomes more commonplace.

Emergence of New Nuclear Club Members

In the next 25 years, several nations may emerge as nuclear powers. These include: Japan, Brazil, Mexico, Argentina, Egypt, Australia, Lybia, Pakistan, West Germany, and the Union of South Africa.

Emergence of New Social Questions

Many new social questions replace those of central concern today. They include the decreasing utility of higher education, chronic unemployment, loss of incentives for investment, and reduced entrepreneurial risk taking.

Recognition of Economic Incompetence

The public in developed countries loses faith in the ability of current institutions to deal with the critical problems of what can be termed economic development and managing an industrialized society. This situation in turn enhances the probability of a new ideology or religion sweeping large population groups.

New Accounting Systems

In some industrial sectors new accounting systems emerge that consider not only profit/loss and cash flow, but also social cost benefit, natural resource use, and pollution. Public opinion experts pressure for the widespread adoption of these accounting systems.

Technological Crises

The following list of crisis areas between 1985 and 1995 derives from Kahn.*

a. Intrinsically dangerous technology:

- Modern means of mass destruction;
- nuclear reactors - fission or fusion;
- nuclear explosives, high-speed gas centrifuges, etc.;
- biological and chemical "progress" including genetic engineering;
- "mind control";
- new techniques for insurgency, criminality, terror or ordinary violence;
- new techniques for counterinsurgency.

b. Gradual worldwide and/or national contamination or degradation of the environment:

- Radioactive debris from various peaceful nuclear uses;
- possible greenhouse or other effects from increased CO_2 in the atmosphere, damage to ozone layer, etc.;
- other special dangerous wastes - methyl mercury, PCB, etc.;
- waste heat;
- other less dangerous but environment degrading wastes such as debris and garbage;
- noise, ugliness and other annoying by-products of many modern activities;
- excessive urbanization;
- excessive overcrowding;
- excessive tourism;
- insecticides, fertilizers, growth "chemicals", food additives, and other chemical "improvements".

---

* H. Kahn and A. Wiener, "The Year 2000".

c. Spectacular and/or multinational contamination or degradation of the environment:

- Nuclear war;
- nuclear testing;
- bacteriological and chemical war or accident;
- artificial moons;
- supersonic transportation (shock waves);
- weather control;
- big "geomorphological" projects;
- million-ton tankers and million-pound planes.

d. Dangerous internal political issues:

- Computerized records;
- other computerized surveillance;
- other advanced techniques for surveillance;
- improved knowledge of, and techniques for, agitprop and other means of creating disturbances;
- improved knowledge of, and techniques for, preventing disturbances;
- complex or critical governmental issues leading to either "technocracy" or "Caesarism";
- nuclear weapons affecting internal politics;

e. Upsetting international consequences:

- Both new and "traditional" demonstration effects;
- technological obsolescence of "unskilled" labor;
- new synthetics - e.g., coffee, raw material substitutes;
- forced modernization;
- inexpensive and widely available "realistic" communications and physical travel;
- inexpensive, possibly synthetic food;
- inexpensive education;
- control and exploitation of the oceans, space, moon.

f. Dangerous personal choices:

- Sex determination of offspring by parents;
- other genetic engineering;
- psychedelic and mood-affecting drugs;
- electronic stimulation of pleasure centers;
- other methods of sensual satisfaction;
- super-cosmetology.

New Political Structures

As more states gain nuclear arms, emerge as economic powers, and resource scarcities develop, the bi-polar or tri-polar world paradigms of the Cold War and detente eras no longer express sociopolitical reality. New groupings and arrangements emerge.

Transition of States to Post-Industrial Societies

During the period of the study, the most advanced states begin to move into a phase of transition from industrial to post-industrial societies.

Emergence of Cartels as Genuine Powers

Cartels based upon natural resources, food, or high-technology items (for example computers, telephone equipment, and military replacement parts) emerge as genuine powers in world affairs. Based upon OPEC's example, cartels formed for price manipulation can be effective if and only if their manipulations are not extreme and noncartelized sources of supply are limited. Cartels influence political affairs through threatened or actual restrictions of supply. Thus, as the economically available supply of raw materials or high-technology items becomes more restricted, cartels gain actual long-term power.

The Marine Environment - The Newest Frontier

Toward the end of the quarter century covered by this study, the marine environment will emerge as a new frontier in its own right. People live permanently on deepwater ports and mining and maricultural installations. The first high-endurance ocean-bottom habitats become operational.

Shifting Government Power

Despite a growing public belief in the inability of governments to cope with complex problems, a perceived lack of an alternative will result in a continued expansion of governmental influcence. However, the relative proportions of local, national, and international power will change with local and international bodies becoming increasingly important.

Capital Shortages

Investment funds for needed, perhaps critical, projects will suffer from spot shortages. Like mortgage markets today, capital markets will become subject to wild fluctuations (interest rate, terms and money supply).

Structural Unemployment

Structural unemployment emerges as a real problem. Demand and/or investment stimulation prove inadequate to deal with it, and politically, it does not disappear. Few are interested in nonskilled jobs and higher education continues to undergraduate in some areas and overgraduate in others. This is due to the confusion regarding the objectives of higher education and the long lead-time involved in the matriculation of students and the development of new courses of study.

Ecotage

Quasi-terrorist groups become active, with their choice of targets motivated by their ecological and political attitudes. The sabotage of nuclear power plant construction projects is an example.

Increasing Paralysis of Government

More of a trend than a specific event, the function of government as a so-called power broker between companies, interest groups, bureaus, political factions, labor organizations, etc., severely limits future choices. The result is the ossification of society, the emergence of a brittle stagnation.

A Growing Subculture of Information Poor

The centrality of information in post-industrial society places a premium on the ability to access and manipulate information, i.e., to use sophisticated new communications technology. Those who have the capability possess a tremendous advantage over those who do not. A new subculture of poverty develops.

Further Shift of Responsibility from Individual to Society

The pervasive, but often ignored, trend to shift responsibility away from the individual accelerates. The individual thinks solely in terms of his or her rights to a good job, education, health care, police protection, retirement security, etc., and dismisses individual responsibility for productivity, risk taking, societal cohesion, etc.

2. Technological Events and the Coast Guard - Direct Impacts

The following technological innovations are likely during the next twenty-five years. These innovations could have a significant impact upon the maritime environment and economy and directly upon the Coast Guard.

(a) Innovations which are considered to have a potential impact upon the Coast Guard's responsibilities in the area of underwater activities include the following:*

- A shift by the United States Navy to a greater reliance upon underwater tactics. Submarines play an increasing role as deterrents, combatants, and as logistic-support vessels. The cargo/troop-transport submarine appears.
- Semipermanent and permanent mining platforms on the ocean bottom are established.
- Offshore energy production facilities grow. These produce, transmit, and use on-site electrical energy from nuclear fission and fusion, the wind, the sun, ocean thermal gradients, and wave action.
- Large maricultural facilities, e.g., fish farms, are located offshore.
- Recreational submersibles, including tour boats, become economically and operationally feasible for a significant segment of the boating public. They have a profound effect on safe boating programs.
- Deepwater ports emerge as the loci for an increasing range of economic, scientific and recreational activities.
- Municipal wastes are treated in a manner to provide nutrients for marine life.
- Many more underwater parks and wilderness areas are established. In addition, such areas emerge as centers for recreation, conservation, and underwater hotels, observation areas, and restaurants.
- Although so-called underwater cities are unlikely for several decades, scientific, military, and commercial underwater habitats are established to perform a wide range of functions.
- Aids to underwater navigation are developed.

---

* Williams, Charles W., et al., Future Underwater Activities and Their Implications for the Coast Guard, Circa 1978-2000

- The Coast Guard is likely to begin operating a limited number of submersibles to perform law enforcement and search and rescue duties.
- Various agencies establish natural forces monitoring stations to provide an early warning of natural events such as earthquakes and tidal waves. Crews on offshore installations, in particular, require adequate, advance warning of potential natural disasters.
- Research is undertaken to establish methods to determine the source and military/non-military nature of a destructive event, threat, and/or attack.
- Weapons emerge whose effects cannot be distinguished from natural phenomena. Research and development projects are initiated to detect and counter these events.
- The Coast Guard establishes an intelligence arm charged with keeping tabs on affairs relating to the underwater environment.

(b) Various innovations cause the extraction of natural resources from the marine environment to be more economically attractive.

(c) Within the next twenty-five years, the United States orbits a solar station which transmits electrical energy to the ground by means of microwaves. Receiving stations could be located at sea.

(d) Vast improvements in food production are likely. New methods, patterns of ownership and management, and adequate distribution could ease the food crisis, although that crisis will not disappear over the next twenty-five years.

(e) Various agencies of the federal government are currently deciding whether or not to allow the manufacture and retail sale of scramblers for use with citizens band radios. If such devices become readily available, either through retail outlets or as home builts, their use in smuggling operations is certain. The same can be said for radio jamming devices. Electronic measures and countermeasures are going to play a greater role in criminal and law enforcement activities.

(f) Toward the end of the study period, fusion reactors are placed in operation to provide power, synthetic materials, and a means of disposing hazardous wastes.

(g) To some extent, a degree of control over local weather conditions is established. While not global control of weather, this will be a step beyond cloud-seeding.

(h) New materials, power plants, and hull forms permit the construction and operation of tankers, breakbulk cargo ships, container ships, and other types, such as lighter aboard ships of greater size and speed.

(i) Over the next twenty-five years, efforts to reintroduce sail driven cargo ships may yield advances. However, success is at first very tenuous. The early entrants, such as Dynaship Corporation in Palo Alto, California, find their efforts highly sensitive to global weather patterns, the price of bunker fuel, construction costs, labor costs, freight rates, cargo handling technologies, international market relationships, capital availability, and the posture of governmental regulation.

(j) Cargo ships may revert to the use of coal in some form.

3. Scenario Descriptions

Following are brief narrative sketches of the three hypothetical scenarios used.

Scenario X - "Surprise-Free"

1980 - The U.S. Economy has been ailing for some time. Band-aid solutions are applied and administrative heads changed without significant impact. Inflation and the bureaucratization of government and industry continues. Entrepreneurial risk-taking is rare, and ethical standards become unfashionable. The U.S. is frequently compared to the slowly decaying Roman Empire. Each vested interest group (business, labor, farmers, ethnic groups) pursues its own aims. Self-interest dominates the common good. As Cowell wrote of Rome, "The rule became 'everyone for himself' . . . the emphasis was increasingly upon private wants, private ambitions, private possessions, personal enjoyment and ease of life." (Ref. 1).

1985 - Hardin's "Tragedy of the Commons" seems inevitable despite the general attitude of "business as usual". A shock wave ripples through the U.S. as it is discovered that preciously unsuspected chemicals are causing large increases in brain damage - - years after exposure.* More stringent environmental regulations are promulgated, but penalties remain ludicrously small. Many polluters ignore the rules, effective enforcement is difficult. The continuing energy shortage results greater dependence on domestic coal reserves. A strong administration is elected in 1988.

1990 - The passage of a number of environmental protection regulations has placed growing law enforcement responsibilities upon the Coast Guard. Research and development on new Coast Guard systems to deal specifically with the marine environment mission are begun. International tensions aggravate resource shortages (e.g., chromium, copper) and create sporadic crises. The administration initiates an austerity program creating an economic recession with considerable unemployment. Research projects to develop substitutes for imported raw materials are undertaken. Transition to solar energy begins. Military budgets are large, but the U.S. does not become involved in a foreign war.

1995 - Austerity has turned the economic situation around. Inflation is at the lowest level in 20 years. Prosperity now returns, despite resources strains. Offshore mining, aquaculture, and other sea-related industries rapidly blossom. substitution of materials is widespread and successful. Solar energy, on a large scale, becomes a major national objective. New types of Coast Guard systems are introduced.

2000 - More environmental damage is uncovered and a major disaster is feared. Despite strong opposition by the ocean-based industries, drastic new environmental regulations are imposed.

---

* Consider an incident in Alvin Toffler's "ecospasm" scenario: The Food and Drug Administrator, Harold Whitwell, requests a meeting with the President on a matter of the "utmost pressing urgency." Whitwell begins by handing the President a 382-page blue-bound report stamped "Top Secret" which proves beyond dispute that a disaster is in the making. Tens of millions of jars and cans of baby food now circulating in the market have been found to contain Arceon Yellow, a dye which tests now show to cause serious mental retardation in infants." (A. Toffler, "Beyond Depression", Esquire, February, 1975, p. 135).

The Coast Guard budget is increased as new marine environment tasks are given to this service.

2005 - Stringent environmental regulations are now internationally accepted. The first successful solar power station is operational.

Scenario Y - "External Threat"

1980 - Unrest and anti-United States activities grow, reflecting the escalating world-wide conflict between the rich and poor nations. The worsening world economy exacerbates the conflict. Castro-style revolutionary activities garner wide support.

1985 - A Latin American government falls to a left-wing popular uprising. The already large illegal immigration into the U.S. doubles, as the middle and upper classes flee the new regime. While cutting critical exports off, the new regime encourages illegal drug traffic to the U.S.

The energy crisis becomes severe in the United States resulting in rationing, enforced conservation, and a renewed reliance upon nuclear power, the development of which has been seriously delayed.

Although its law enforcement duties grow, the Coast Guard is ordered to reduce energy consumption.

1990 - Training of terrorists in Latin America expands in the struggle for liberation from U. S. "domination". Kidnappings and "executions" of U.S. citizens increase. Several countries shut off oil to the United States. Uprisings are fomented in Puerto Rico and there is fear of a "fifth column" in New York.

Research and development on surveillance systems is drastically increased, and the Coast Guard budget doubled. The Coast Guard is placed on emergency status, and patrols and inspections of ships are tightened.

The U. S. begins to use food as a weapon in dealing with developing countries which withhold raw materials. A nuclear explosion occurs off San Diego; few people are killed but serious radiation effects are feared. There is panic in several cities. One result is a U.S. moratorium on nuclear power plant construction. Liquified coal and photovoltaic cells are supported as alternative power sources. Leisure boating suffers a sizeable decline as fears of nuclear terrorism increase.

1995 - The U. S. has taken strong military defense measures and Latin America reacts by increasing anti-U.S. terrorist activities.

The Southwestern U.S. loses population. There are detention camps for "enemy aliens" in New York, Florida, Texas, New Mexico, Arizona, and California. The conflict has led to delays in developing new energy sources. The U.S. and Western Europe, also having difficulties with developing countries, form technology and food cartels to counter the "Southern threat".

A "sea barrier" sealing the U.S. coast is established by the Navy and Coast Guard.

2000 - The external situation has calmed down for the United States as cooperation proves more fruitful than confrontation for all concerned. Nuclear power development resumes in the United States, and major achievements are reported in fusion research and development.

2005 - The Coast Guard budget is cut in half as peace prevails.

The economy suddenly declines resulting in a severe depression and massive unemployment. In a matter of months, a fanatical new religious-political ideology stressing ascetism and conformity spreads rapidly through the United States, it is expected to take political power in 2008.

Scenario Z - "Internal Shifts"

1980 - The economic situation of the late 1970's continues to worsen in the early 1980's. Inflation, low (perhaps negative) rates of growth, continued dependence upon foreign sources of oil and other raw materials, and high rates of unemployment and underemployment continue. Contemporary economic and political instutions, considered by some to be obsolete, ineffectual and even dangerous, come under increasing criticism. Critics, such as Hazel Henderson, who have proclaimed the bankruptcy of traditional economic theory and the "big-machine approach" gain a wide audience. Decentralization becomes the rallying cries of the political day and the socially chic evening. Federal spending on welfare, public health program, and the cities, and government regulation of business and citizens' private lives are increasingly challenged. Revenue sharing is seen as a trap, and the civil service is the object of a bitter campaign. Liberalism is dead; libertarianism gains strength. A new age of the individual is in the ascendent. However, the practical requirements of managing the economy take precidence over political ideology. The sociocultural climate becomes paradoxical as old and new coexist.

The mid-twentieth century style corporation remains vital only where it is relatively small, or where it takes a flexible, leading role in the new changes. On the darker side, the confused conditions also breed revivals of various radical groups, including the Klu Klux Klan.

Regarding the effect of these conditions on the Coast Guard:

1. Privately owned and operated submersibles become popular and less expensive;
2. several new deep-water port projects begin construction;
3. offshore drilling activities reach a new level of intensity;
4. first nationally important occurrences of ecotage (the sabotage of plants and/or projects for "ecological motives") gain national attention;
5. the Coast Guard establishes its own intelligence capability to gather and analyze data on smuggling, terrorism, and ecotage;
6. considerations of the Coast Guard's responsibilities in the underwater environment remain speculative and/or in the realm of long-range planning.

1985 - The economy is at its lowest point. Inflation and unemployment are severe. The "old" institutions have been largely ineffectual, crippled, or effectively dismantled. In the absence of new institutions and a new management approach, the economy and society flounder.

The society is polarized, each group attempting to improve its own position. The public debate regarding the country's future is acrimonious. Within this political context, the federal government manages to reduce its budget by shifting functions to state and local governments, and by reducing all activities not directly related to the assurance at a stark social welfare. The definition of the federal poverty level is lowered: recipients who can work are removed from welfare eligibility. Minimum wage laws are repealed, and the tax structure revised to encourage: (1) The use of labor - the one vital resource in ample supply - and (2) the use of savings for capital formation. Government subsidies to agricultural, business and industrial groups are drastically reduced. They are told to "sink or swim".

However, these measures are not adequate. The impacted institutions cannot adjust with sufficient rapidity. In this economic hodge-podge, many paradoxical situations arise. For example, in the area of metals, the domestic producers of a given metal may not be able to meet demand, yet import restrictions could remain in force. At the same time, the demand for the given metal could remain significantly above the legally available supply. Thus, steel, copper, or chrome (to mention only a few possibilities) could become black-marketed and/or smuggled items. The same situation could happen in reverse - the illegal export of items in high demand overseas. The groups falling on hard times turn to crime as a means of support, thus smuggling activities increase dramatically. Further, United States' fishing grounds are raided by both domestic and foreign fishing fleets.

Public pressure for meaningful environmental regulation increases. Many demonstrations turn violent, and incidents of ecotage - some serious, some almost comic - proliferate although they are denounced by responsible groups. The general public receives those demonstrators who are captured and tried as folk heroes.

In terms of energy, an unexpected breakthrough in fusion power is achieved, resulting in a surge of public and governmental optimism. Researchers warn, however, that it will be some years before fusion power "comes on-line".

Investment in offshore industrial facilities continues at a high rate. In fact, offshore capital investment becomes a significant percentage of all capital investment.

Using a private submersible, a crime syndicate begins a series of strikes against offshore installations. These strikes culminate in the destruction of an offshore refinery. Following this event, the security in and around offshore installations is dramatically increased. A major underwater accident killing a large number of workers draws attention to underwater safety.

The effect on the Coast Guard of these events is as follows:

1. The expense of recreational submersibles decreases markedly as production increases. The Coast Guard undertakes the licensing of operators and manufacturers. Operational areas for submersible use are set aside.
2. Private police units proliferate as the Coast Guard and other law enforcement agencies become overworked and are provided with obsolete equipment, and as their social standing declines.
3. Because of the increased threat to offshore industry and recreation, the Coast Guard begins systematic studies of underwater safety and security requirements.

1990 - Economic decline continues into the early part of the 1990's; however, the decade marks the bottom of the economic slide. The country's major economic institutions are reorganized and reformed. Many of the domestic functions of the federal government, such as those performed by the Departments of HEW and HUD, are regionalized. States, counties, and cities also regionalize many of their functions. Economic recovery, relief and development of alternative energy sources are emphasized. National coordination of efforts focus upon information sharing and joint planning commissions. Federal and corporate paternalism are rejected. Anti-pollution laws are strengthened and enforced.

The movement of industry offshore accelerates. Such locations are viewed as relative havens for socially sensitive industrial processes. Domestic political terrorist and criminal groups become steadily more active, and incidents of gun-running into the United States are commonly reported in the press. There is an unproved suspicion of substantial foreign involvement. Beset by domestic problems, the United States' international position declines as does Europe's.

In regard to the Coast Guard:

1. Ecotage steadily increases, indistinguishable from other terrorist activity;
2. the Coast Guard fights pressure to transfer major components to regional governmental bodies;
3. there is a continued study of underwater safety and security issues. Prototype "underwater cutters" are built and field tested.

1995 - In 1995, there are indications of an economic and sociocultural recovery, but the recovery itself has not yet begun. On the other hand, new theoretical and managerial instruments are being researched, developed, and tested. The new institutions are gaining self-confidence, public confidence, and competence. The threat to offshore installations and the overall crime rates have declined, but industry's interest in moving offshore grows. Many positive benefits of offshore locations have been discovered: energy generation from ocean thermal gradients, wind, solar, and wave sources; ease of transportation via deep-draft cargo ships; and often more aesthetic settings. The first large-scale commercial ocean mining projects are begun. The first ocean thermal gradient power plants are established, initially serving as an auxiliary power source but eventually becoming a primary one.

Terrorist and ecotage groups continue to operate, although not as effectively as before. The big news is that the intelligence community is able to prove - and does so publicly - that many terrorist, ecotage, and environmental action groups have been used, or set up in the first place, as dupes for natural-resource cartels.

After several months of investigation, in an atmosphere reminiscent of the Watergate Scandal, the press reports that many elected officals and member of the bureaucracy, have accepted large payoffs from foreign cartels and governments in return for legislation and regulatory actions intended to <u>reduce</u> natural resource production from domestic resources. The new scandal runs true to form; eventually a governmental investigation is launched, a few minor figures are convicted, and an "Oilgate" takes its place beside the nation's other great scandals.

However the exposure and censure do not run as deeply as its corruption itself. The mass media largely ignore the efforts to correct the damage, and the public wrongly assumes that corrections are being made. Slowly and quietly, while the nation's major bureaus and corporations wait for the other shoe to drop, investigative teams undertake a comprehensive review of regulatory legislation, lobbying, decisions, and actions.

During this period:

1. Overall Coast Guard funding is increased in response to its increased duties and the additional cost of the new organizational format.
2. Coast Guard effectiveness dramatically increases for most of its primary functions, and its public image also improves.
3. Coast Guard is involved in a comprehensive review of its practices with regard to enforcement of laws and treaties and vessel safety.
4. Underwater Safety and Security Program is established as a distinct entity. The Coast Guard begins regular operation of "underwater cutters and SAR boats".

2000 - The overall situation has improved dramatically. The new sociopolitical institutions have their feet on the ground, and the relations between government and industry have taken on a pragmatic rough-and-ready nature. Problems are detected, defined, and dealt with rapidly. The theoretical and empirical foundations are in place, and action is possible. Nothing is seen as fixed, and the public debate rages on, although no longer at levels near hysteria. Economics has integrated many ecological principles and has regained a good deal of vitality. Ecology has integrated many economic and political principles and provides a more useful body of understanding. In short, a new sociopolitical common ground has been formed. The economic crisis is over.

International environmental protection treaties are signed and enforced, resulting in noticable improvement in the marine environment. Terrorism and ecotage continue to be problems despite the improving situation. New counter measures are taken, and certain specific civil liberties and social privileges are restricted as part of the anti-terrorist/ecotagist campaign. The public grudgingly accepts these measures as "temporary". Eventually, the restrictions "melt into the background".

The recreational use of the maritime environment increases. Obsolete offshore installations, such as drilling platforms, are developed as resorts, marine parks, and maritime museums.

Ocean thermal gradient plants produce significant amounts of electrical energy and fertilizer. The energy shortage in many coastal areas is eased. The new sources of fertilizer replaces petroleum-based production, easing the petroleum shortage. Although the energy situation has improved, its basic problem has not been solved.

The movement of industry offshore continues. Large industral parks are established. Although the term is actually incorrect, the popular press hails these installations as "cities in the seas".

The Coast Guard is affected by these events in several ways:

1. Under the new international agreements, there is an expansion of the law enforcement, safety, and environmental activities.

2. Its anti-terrorist/ecotage activities become more effective and sophisticated.

3. The improved economy causes minor problems in recruitment.

4. Underwater Safety and Security (USS) research programs develop improved rescue equipment and aids to underwater navigation.

2005 - The economic recovery continues, and the remaining problems attendant to regionalization are being worked out. However, the sociocultural situation is more clouded than five years ago. The real geopolitical power of the natural-resource cartels revives, along with the general improvement in economic activity. Western Europe is hardest hit by the renewed Third-World militancy, and a struggling United States economy undertakes the added strains of increased foreign aid and of ensuring minimal raw material and energy supplies for Western Europe. The newly generated economic surpluses are turned toward the capital investments needed to improve the "environmental performance of industry" and to take care of maintenance of plant and equipment. They are also directed into critical foreign investment. Thus, out of the recovery-based prosperity, many past-due bills must be paid.

New international environmental monitoring and reporting agencies are established, and still higher standards of environmental quality are required of business, industry, and the general public. The new regulations are more complex and are thus more difficult to comply with and to enforce.

The trend toward industrial development off-shore has finally captured the public imagination as the space program did in the 1960's. The first true mining operations are established on the ocean bottom. The installation includes a permanent habitat, ore pre-processing facilities, transportation facility, and, of course, the mine itself. Remotely controlled machines do the actual digging.

The use of the marine environment for leisure activities continues to grow. Sailing, power-boating, diving, submersible-boating, swimming, and "underwater camping" enjoy steady growth. The safety of many of these activities is widely debated.

Thus, the image which emerges of the United States in 2005 is one of a nation which has come through a long crisis. The political structure and economic structure has been vastly altered; new safeguards on individual liberty have enacted, and terrorism and ecotage have been controlled. With the added stimulas of the "marine economy", the national economy is recovering. The most critical remaining problem is managing the domestic effects of the geopolitical pressures exerted by the resource-rich, but economically poor countries.

For the Coast Guard, the above situation has the following effects:

1. Due to fiscal pressures, the budget is reduced.
2. Continued growth occurs in the its Underwater Safety and Security Program. New submersible patrol and rescue vessels are added to the fleet.
3. It establishes underwater monitoring stations in heavy traffic areas.
4. New environmental regulations pose difficulties of detection and enforcement.
5. Budget restrictions force a "make-do" policy with regard to equipment in most programs.
6. Its Marine Environment Protection program takes on an international role of monitoring and education.

4. Events used in Scenarios X, Y, and Z

The following table summarizes the events which comprise the scenarios developed in the preceding section.

Table A-1

EVENTS USED IN THE SCENARIOS

	X	Y	Z
Energy and Materials			
Material shortages	1990		
Short-term energy shortages			1980
Severe energy shortages		1985	
An all-out push toward coal	1980		
Beginnings of shift to alternative sources	1990		
New energy source development delayed		1995	
Major "nuclear effort" launched		1985	
Nuclear curtailed, alternative source pushed		1990	
Nuclear is 3% to 5% of U. S. total	2000		
Nuclear effort resumes		2000	
Solar sources become national objective	1995		
Solar power station in orbit	2005		
Breakthrough in fusion research			1985
First ocean thermal gradient plant (OTEC)			1995
OTEC's recognized as significant			2000
Easing of energy shortages in coastal areas			2000
Material/energy fluctuation hits Europe hard, U. S. aids			2005
International Cartels			
U. S. and Europe farm food and tech. cartels		1995	
Cartels move into political vacuum			1980
U. S. domestic pressure on multinationals	1995		
Effects in U. S. of multinationals more known	1995		
Widespread U. S. scrutiny of multinationals	1995		
Remaining question: How to deal with cartels?			2005
Power of cartels return after economic down-turn			2005
Nuclear Proliferation			
Proliferation of nuclear plants in third world	1980		
Proliferation of nuclear weapons		1980	
Environmentalist Movements and Issues			
Increased demands for tight regulations	1985		
New types of pollution are discovered	1985		
Advent of environmental hysteria	1985		
More strict regulations enacted	2000		
Environmental concerns less hysterical	2000		2000
Marine environment improves			2000
Further strengthening of regulations			2005
Admission that new regulations are hard to enforce			2005

	X	Y	Z
Foreign Events			
Tension between "rich" and "poor" worlds escalates		1980	
"Castro-type" movements gain popularity in Latin America		1980	
Malnutrition widespread in Latin America	1980		
Raw materials trade used as a political weapon	1985		
Collapse of Latin American agriculture		1985	
Doubling of Latin immigration to the U. S.		1985	
Latin government falls to a left-wing coup		1985	
Critical exports to U. S. are halted from one Latin country		1985	
Food shortages in Latin America	1990		
Uprising formented in Puerto Rico, unrest in New York	1990		
Other countries halt oil exports to U.S.	1990		
International status of U. S. declines sharply			1990
Europe also comes under fire			1990
U. S. witholds food from countries witholding resources		1990	
External situation for U. S. stabilized		2000	
Latin America in new cooperative era		2000	
International environmental protection treaties			2000
U. S. relations with Latin America stronger, more positive attitude		2005	
New international environmental regulations	2005		
Terrorism-Foreign and Domestic			
First nationally recognized important ecotage			1980
Widespread ecotage			1985
Domestic political terrorism increases			1990
Ecotage and political terrorism become indistinguishable			1990
Expanded training of terrorist in Latin America		1990	
Nuclear explosion off San Diego. Widespread panic		1990	
Broadly-based anti-U. S. terrorist activities		1995	
Ecotage groups suffer reduced effectiveness			1995
Natural resource cartels backing some ecotage groups			1995
New anti-terrorist actions accepted as necessary			2000
Overall level of crime increases			1985
Latin government encourages drug smuggling		1985	
Crime syndicate use of mini-subs in extortion			1985
Overall crime rate begins to decline			1995
Maritime Economy			
Leisure boating declines		1990	
Leisure boating increases		2005	
Private submersibles become more popular			2000
Several deep-water port projects are begun			1980
Offshore drilling reaches a new, higher level			1980
Maritime economy becomes established			1985

	X	Y	Z
Maritime Economy			
Leisure boating declines		1990	
Leisure boating increases		2005	
Private submersibles become more popular			2000
Several deep-water port projects are begun			1980
Offshore drilling reaches a new, higher level			1980
Maritime economy becomes established			1985
Offshore industry investments significant fraction of new industrial investments		1995	
Accelerated movement of industry offshore			1990
Press popularizes cities on the seas			2000
Offshore economy captures public imagination			2005
Marine environment is a new frontier			2005
Maritime leisure increases			2005
Domestic Politics			
Single issue politics continues to grow	1980		
"Economics" recognized as "incompetent"	1980		
General economic decline	1990		
Popular campaign to reduce federal activities			1980
Political extremism is revived			1980
Social floundering			1985
Intergroup conflict increases			1985
Societal-futures debate becomes acrimonious			1985
Many economic subsidies are repealed			1985
Selected federal functions transferred to state/local			1985
Blackmarket sub-economy develops			1985
Nuclear-power debate becomes critical	1985		
Labor-based (as opposed to capital-based) production pushed			1985
Agencies such as HUD and HEW are regionalized			1990
Institutionalization of labor-based production encouraged			1990
Federal and corporate paternalisms are rejected			1990
Economy bottoms out			1990
Despite cutbacks, continued federal influence			1990
Investigations of regulatory abuses in resource areas			1995
European style guest-worker program established			1995
Post-Keynesian economic theory "takes off"			1995
Economy is firming up	1995		
New wave of trust busting	1995		
Out migration from American Southwest		1995	
End of severe social crisis			2000
Federal regionalization is beginning to work			2005
Severe depression		2005	
New religious-political ideology spreads		2005	
Corporations vital if progressive			1980
Quality of public instruction hits bottom	1990		
Technology			
Technology emerges as defined managerial class	1980		
Materials substitution	1990		
R&D on U.S.C.G.'s surveillance systems increased		1990	
New social questions regarding technology	1995		
Paralysis of technology research and development			2000
First waves of an outward "brain drain"			2000

	X	Y	Z
United States Coast Guard			
Coast Guard establishes an intelligence arm	1985	1985	1980
Material movement toward "unionization"	1985		
Continued high military budgets	1990		
Prototype undersea vessels tested by Coast Guard	1990		
Increased public accountability of Coast Guard	1995		
Increased Coast Guard anti-smuggling and illegal acts	1995		
Coast Guard budget increases	2000	1990	1995
Coast Guard role in marine environmental protection increases	2005		
Coast Guard anti-terrorist role expands		1980	
Coast Guard military role re-thought		1980	
Coast Guard counter insurgency training		1985	
Coast Guard ordered to reduce fuel use		1985	
Coast Guard on emergency status		1990	
Review of Coast Guard actions 1990-1995 begun		1995	
Illegal immigration declines; Coast Guard still active		1995	
U.S. establishes a "sea barrier"		2000	
Coast Guard adds new vehicles		2000	
Coast Guard budget reduced		2005	2005
Early planning for underwater mission			1980
Private police units proliferate			1985
Specific planning of an underwater security and surveillance mission			1985
Expanded underwater recreational vehicle use			1985
Continued study of underwater missions			1990
Increased Coast Guard effectiveness			1995
Coast Guard review of ELT and vessel safety			1995
Underwater safety and security program begun			1995
New level of Coast Guard effectiveness in anti-terrorism			2000
Minor recruitment problems			2000
Underwater security and surveillance program sponsors extensive R&D			2000
Coast Guard expanded role in ELT			2000
Budget restrictions force "make do"			2005
Submersibles added to Coast Guard fleet			2005
Underwater monitoring stations established			2005

REFERENCE

1. F.R. Cowell, "Cicero and the Roman Republic", Chanticleer Press, New York, 1948, p. 276.

APPENDIX B

Details on Cross-Impact Analysis

1. <u>Long Term versus Short Term Impacts</u>

a. <u>Variation K1</u>

<u>Short Term Impacts</u>

Environmental Regulation → Fuel Adequacy: - .15 instead of - .25
Ocean Pollution → Environmental Regulation: + 0.1 instead of + 0.3
Offshore Industry → Resource Shortage: -.05 instead of - 0.1
Technological Advances → Fuel Adequacy: + 0.3 instead of +0.1

Interpretation of Above Short Term Changes:

* Environmental regulations will hamper the fuel adequacy less;
* environmental regulations will be tightened up more as ocean pollution increases;
* off-shore industries make a greater contribution to reducing the shortages;
* technological advances help more in meeting the fuel requirements.

TIME UNIT* ↓	G 1	C 2	B 3	E 4	O 5	S 6	U 7	I 8	T 9	M 10	R 11	OW 12
1.0	0.90	0.30	0.50	0.50	0.50	0.30	0.10	0.10	0.50	0.50	0.20	0.50
2.0	0.90	0.33	0.52	0.50	0.47	0.32	0.12	0.13	0.53	0.53	0.23	0.50
3.0	0.90	0.38	0.52	0.49	0.47	0.36	0.18	0.17	0.56	0.56	0.25	0.50
4.0	0.89	0.42	0.52	0.49	0.48	0.41	0.24	0.22	0.59	0.59	0.27	0.50
5.0	0.88	0.46	0.53	0.49	0.49	0.45	0.33	0.28	0.62	0.62	0.28	0.50
6.0	0.87	0.50	0.54	0.50	0.51	0.48	0.42	0.34	0.65	0.65	0.29	0.50
7.0	0.86	0.53	0.55	0.50	0.53	0.52	0.52	0.40	0.68	0.68	0.30	0.50
8.0	0.85	0.57	0.56	0.51	0.55	0.54	0.61	0.46	0.70	0.70	0.30	0.50
9.0	0.84	0.60	0.58	0.52	0.58	0.57	0.69	0.53	0.73	0.72	0.30	0.50
10.0	0.83	0.63	0.59	0.53	0.59	0.59	0.76	0.59	0.75	0.75	0.30	0.50
11.0	0.82	0.65	0.61	0.53	0.61	0.61	0.81	0.64	0.77	0.77	0.30	0.50
12.0	0.81	0.68	0.63	0.54	0.62	0.63	0.85	0.70	0.79	0.78	0.29	0.50
13.0	0.81	0.70	0.65	0.54	0.63	0.65	0.89	0.74	0.81	0.80	0.29	0.50
14.0	0.80	0.72	0.67	0.54	0.63	0.66	0.91	0.78	0.83	0.82	0.28	0.50
15.0	0.80	0.74	0.69	0.55	0.64	0.68	0.93	0.82	0.84	0.83	0.27	0.50
16.0	0.80	0.76	0.71	0.55	0.63	0.69	0.95	0.85	0.86	0.85	0.27	0.50
17.0	0.81	0.78	0.73	0.54	0.63	0.70	0.96	0.88	0.87	0.86	0.26	0.50
18.0	0.81	0.80	0.75	0.54	0.62	0.71	0.96	0.90	0.88	0.87	0.25	0.50
19.0	0.82	0.81	0.77	0.54	0.61	0.72	0.97	0.92	0.89	0.88	0.24	0.50
20.0	0.82	0.83	0.78	0.54	0.59	0.73	0.98	0.93	0.90	0.89	0.23	0.50

*See first footnote, p. 20.

TABLE B-1

b. Variation K3

Short Term Impacts

* Outside World → Resource Shortage: 0.2 instead of 0
* Ocean Pollution → Fuel Adequacy: -0.05 instead of 0
* Resource Shortage → Technological Advances: 0.2 instead of 0
* Resource Shortage → Maritime Commerce: 0.1 instead of 0.
* Environmental Regulation → Ocean Pollution: 0.05 instead of 0

Interpretation of these Changes:

The core implication here is that there are additional, significant interactions which can occur in the shorter time frame. These changes increase the density of the beta matrix, by adding 5 additional values, three positive, two negative.

* The matrix now shows a link between the outside world and resource shortage. This is necessary to account for event such as the Iranian oil cut-off.
* A negative interaction between ocean pollution and fuel adequacy is added to indicate that increased pollution can alter the fuel adequacy in the short term since any pollution mishaps will have to be cleaned up regardless of whether the environmental regulations exist or not.
* Resource shortage will create opportunities for short-term technological fixes, e.g., practices of insulation, co-generation technologies and building of peaking units.
* Resource shortages can produce opportunities for maritime commerce, e.g., resulting from the shift in supply sources and commodities.
* Environmental regulation will have some impact even in the short term on ocean pollution.

RESULTING BEHAVIOR

TIME UNIT	G	C	B	E	O	S	U	I	T	M	R	OW
↓	1	2	3	4	5	6	7	8	9	10	11	12
1.0	0.90	0.30	0.50	0.50	0.50	0.30	0.10	0.10	0.50	0.50	0.20	0.50
2.0	0.90	0.37	0.52	0.50	0.47	0.32	0.12	0.13	0.53	0.53	0.23	0.50
3.0	0.89	0.38	0.52	0.47	0.47	0.36	0.18	0.17	0.58	0.57	0.24	0.50
4.0	0.89	0.42	0.52	0.47	0.49	0.41	0.24	0.22	0.61	0.61	0.25	0.50
5.0	0.87	0.46	0.53	0.49	0.50	0.44	0.33	0.28	0.65	0.64	0.26	0.50
6.0	0.85	0.47	0.55	0.50	0.52	0.47	0.42	0.34	0.68	0.66	0.26	0.50
7.0	0.83	0.53	0.57	0.52	0.54	0.50	0.52	0.40	0.70	0.67	0.26	0.50
8.0	0.81	0.56	0.59	0.54	0.56	0.52	0.61	0.46	0.72	0.71	0.25	0.50
9.0	0.78	0.58	0.61	0.56	0.58	0.54	0.69	0.53	0.74	0.73	0.24	0.50
10.0	0.74	0.61	0.63	0.58	0.59	0.56	0.76	0.58	0.76	0.75	0.23	0.50
11.0	0.73	0.64	0.65	0.59	0.60	0.57	0.81	0.64	0.77	0.77	0.22	0.50
12.0	0.72	0.66	0.68	0.60	0.61	0.59	0.85	0.69	0.79	0.79	0.21	0.50
13.0	0.71	0.68	0.70	0.61	0.61	0.60	0.89	0.73	0.80	0.80	0.20	0.50
14.0	0.71	0.70	0.72	0.61	0.61	0.61	0.91	0.77	0.81	0.82	0.19	0.50
15.0	0.71	0.72	0.74	0.61	0.61	0.63	0.93	0.80	0.82	0.83	0.18	0.50
16.0	0.71	0.74	0.75	0.60	0.60	0.64	0.94	0.83	0.83	0.84	0.17	0.50
17.0	0.72	0.76	0.77	0.60	0.59	0.65	0.96	0.86	0.84	0.85	0.16	0.50
18.0	0.72	0.78	0.79	0.59	0.58	0.66	0.97	0.88	0.85	0.87	0.15	0.50
19.0	0.73	0.80	0.80	0.58	0.56	0.67	0.97	0.90	0.86	0.88	0.14	0.50
20.0	0.73	0.82	0.82	0.56	0.55	0.68	0.98	0.92	0.87	0.89	0.13	0.50

TABLE B-2

c. Variation K_5

ALPHA VALUE MATRIX

		G 1	C 2	B 3	E 4	O 5	S 6	U 7	I 8	T 9	M 10	R 11	OW 12
G	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	3	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E	4	0.00	0.00	0.00	0.00	-0.20	0.00	0.00	-0.05	0.00	0.00	0.00	0.00
O	5	-0.10	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	8	-0.05	0.00	0.02	0.00	0.05	0.00	0.00	0.00	0.00	0.00	-0.10	0.00
T	9	0.20	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	-0.20	0.00
M	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R	11	-0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00
OW	12	0.00	0.20	0.10	0.00	0.00	0.10	0.00	0.00	0.10	0.20	0.40	0.00

BETA VALUE MATRIX

		G 1	C 2	B 3	E 4	O 5	S 6	U 7	I 8	T 9	M 10	R 11	OW 12
G	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	2	-0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	3	-0.05	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E	4	-0.25	0.00	0.00	0.00	-0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O	5	-0.05	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	6	-0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U	7	-0.05	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	8	0.00	0.00	0.00	0.00	0.15	0.00	0.30	0.00	0.00	0.00	-0.10	0.00
T	9	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	10	-0.10	0.00	0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00
R	11	0.00	0.10	-0.20	0.00	0.00	0.20	0.00	0.00	0.20	0.10	0.00	0.00
OW	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00

OUTPUT

TIME UNIT ↓	G 1	C 2	B 3	E 4	O 5	S 6	U 7	I 8	T 9	M 10	R 11	OW 12
1.0	0.90	0.30	0.50	0.50	0.50	0.30	0.10	0.10	0.50	0.50	0.20	0.50
2.0	0.90	0.33	0.52	0.52	0.48	0.32	0.12	0.13	0.53	0.53	0.23	0.50
3.0	0.88	0.38	0.52	0.51	0.48	0.36	0.17	0.16	0.57	0.57	0.24	0.50
4.0	0.86	0.42	0.52	0.53	0.50	0.41	0.23	0.20	0.61	0.61	0.25	0.50
5.0	0.83	0.46	0.54	0.56	0.51	0.44	0.31	0.24	0.65	0.64	0.26	0.50
6.0	0.80	0.49	0.55	0.59	0.53	0.47	0.39	0.29	0.68	0.66	0.26	0.50
7.0	0.75	0.52	0.57	0.62	0.55	0.50	0.48	0.34	0.70	0.67	0.26	0.50
8.0	0.70	0.56	0.59	0.65	0.57	0.52	0.57	0.39	0.72	0.71	0.25	0.50
9.0	0.65	0.58	0.61	0.68	0.59	0.54	0.65	0.45	0.74	0.73	0.24	0.50
10.0	0.59	0.61	0.63	0.71	0.60	0.56	0.72	0.50	0.76	0.75	0.22	0.50
11.0	0.53	0.63	0.65	0.73	0.62	0.57	0.78	0.55	0.77	0.77	0.21	0.50
12.0	0.48	0.66	0.68	0.75	0.63	0.58	0.82	0.59	0.78	0.79	0.20	0.50
13.0	0.43	0.68	0.70	0.77	0.64	0.59	0.86	0.64	0.79	0.80	0.18	0.50
14.0	0.38	0.70	0.72	0.79	0.64	0.60	0.89	0.67	0.80	0.81	0.16	0.50
15.0	0.35	0.72	0.74	0.80	0.64	0.61	0.91	0.71	0.81	0.83	0.15	0.50
16.0	0.31	0.74	0.76	0.82	0.65	0.62	0.93	0.74	0.82	0.84	0.13	0.50
17.0	0.28	0.75	0.78	0.83	0.64	0.63	0.94	0.77	0.83	0.85	0.12	0.50
18.0	0.26	0.77	0.80	0.83	0.64	0.64	0.96	0.80	0.83	0.86	0.10	0.50
19.0	0.24	0.79	0.81	0.84	0.64	0.65	0.96	0.82	0.84	0.87	0.09	0.50
20.0	0.23	0.80	0.83	0.85	0.63	0.66	0.97	0.84	0.85	0.88	0.08	0.50

d. **Variation K_7**

Same alpha matrix as K_5, beta matrix zero.

OUTPUT

TIME UNIT ↓	G 1	C 2	B 3	E 4	O 5	S 6	U 7	I 8	T 9	M 10	R 11	OW 12
1.0	0.90	0.30	0.50	0.50	0.50	0.30	0.10	0.10	0.50	0.50	0.20	0.50
2.0	0.90	0.33	0.52	0.52	0.48	0.32	0.12	0.13	0.53	0.53	0.23	0.50
3.0	0.89	0.37	0.53	0.53	0.45	0.34	0.15	0.16	0.56	0.56	0.25	0.50
4.0	0.89	0.40	0.55	0.55	0.43	0.35	0.18	0.20	0.59	0.59	0.27	0.50
5.0	0.89	0.44	0.57	0.56	0.40	0.37	0.22	0.24	0.62	0.62	0.29	0.50
6.0	0.88	0.47	0.59	0.57	0.38	0.39	0.26	0.29	0.65	0.65	0.31	0.50
7.0	0.88	0.51	0.60	0.59	0.36	0.41	0.30	0.34	0.68	0.68	0.32	0.50
8.0	0.87	0.54	0.62	0.60	0.33	0.43	0.35	0.40	0.71	0.70	0.33	0.50
9.0	0.87	0.57	0.64	0.61	0.31	0.44	0.40	0.46	0.73	0.72	0.33	0.50
10.0	0.86	0.60	0.65	0.62	0.29	0.46	0.45	0.51	0.76	0.75	0.34	0.50
11.0	0.86	0.63	0.67	0.62	0.27	0.48	0.50	0.57	0.78	0.77	0.34	0.50
12.0	0.86	0.66	0.68	0.63	0.25	0.47	0.55	0.62	0.80	0.78	0.33	0.50
13.0	0.85	0.68	0.70	0.64	0.23	0.51	0.59	0.67	0.82	0.80	0.33	0.50
14.0	0.85	0.71	0.71	0.65	0.21	0.53	0.64	0.71	0.84	0.82	0.32	0.50
15.0	0.85	0.73	0.73	0.65	0.19	0.54	0.68	0.75	0.85	0.83	0.30	0.50
16.0	0.85	0.75	0.74	0.66	0.18	0.56	[illegible]	0.79	0.86	0.85	0.29	0.50
17.0	0.85	0.77	0.76	0.66	0.16	0.59	0.76	0.82	0.88	0.86	0.28	0.50
18.0	0.85	0.79	0.77	0.67	0.15	0.57	0.79	0.85	0.89	0.87	0.26	0.50
19.0	0.85	0.81	0.78	0.67	0.13	0.61	0.82	0.87	0.90	0.88	0.24	0.50
20.0	0.85	0.83	0.80	0.67	0.12	0.62	0.84	0.89	0.91	0.89	0.22	0.50

Interpretation of Changes between K_5 and K_7:

The difference between K_5 and K_7 is the total elimination of the beta matrix in the latter. There are 23 short term effects in K_5, none in K_7.

* There is a significant improvement in Coast Guard fuel adequacy when 7 negative short term impacts on G are eliminated.

* The elimination of the strong positive short term impact of ocean pollution on environmental regulation reduces the latter somewhat.

* Elimination of the four short term contributors to ocean pollution reduces that problem drastically.

2. Importance of Technology

VARIATION K6 - TECHNOLOGICAL PESSIMISM

K.6 ALPHA VALUE MATRIX

		G	C	B	E	O	S	U	I	T	M	R	OW
		1	2	3	4	5	6	7	8	9	10	11	12
G	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	3	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E	4	0.00	0.00	0.00	0.00	-0.10	0.00	0.00	0.05	0.00	0.00	0.00	0.00
O	5	-0.10	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	8	-0.05	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	-0.10	0.00
T	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R	11	-0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00
OW	12	0.00	0.20	0.10	0.00	0.00	0.10	0.00	0.00	0.10	0.20	0.40	0.00

BETA VALUE MATRIX

		G	C	B	E	O	S	U	I	T	M	R	OW
		1	2	3	4	5	6	7	8	9	10	11	12
G	1	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00
C	2	[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	3	-0.10	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E	4	-0.05	0.00	0.00	0.00	-0.05	0.00	0.10	0.00	0.00	0.00	0.00	0.00
O	5	-0.05	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	6	-0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U	7	-0.05	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	8	[illegible]	0.00	0.00	0.00	[illegible]	0.00	0.10	0.00	0.00	0.00	-0.10	0.00
T	9	[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	10	[illegible]	0.00	0.00	0.00	0.10	0.10	0.00	[illegible]	[illegible]	0.00	0.00	0.00
R	11	0.00	[illegible]	-0.20	0.00	[illegible]	0.20	0.10	[illegible]	0.20	0.10	0.00	0.00
OW	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00

OUTPUT

TIME UNIT	G	C	B	E	O	S	U	I	T	M	R	OW
↓	1	2	3	4	5	6	7	8	9	10	11	12
1.0	0.90	0.30	0.50	0.50	0.50	0.30	0.10	0.10	0.50	0.50	0.20	0.50
2.0	0.89	0.33	0.52	0.52	0.48	0.32	0.10	0.10	0.53	0.53	0.26	0.50
3.0	0.85	0.39	0.50	0.51	0.47	0.38	0.10	0.11	0.59	0.55	0.32	0.50
4.0	[illegible]	0.44	0.47	0.52	0.46	0.45	0.11	0.12	0.66	0.62	0.38	0.50
5.0	0.72	0.50	0.45	0.52	0.45	0.52	0.11	0.13	0.71	0.67	0.44	0.50
6.0	0.62	0.55	0.43	0.53	0.43	0.59	0.12	0.15	0.76	0.71	0.49	0.50
7.0	0.50	0.59	0.41	0.53	0.42	0.64	0.13	0.17	0.81	0.74	0.55	0.50
8.0	0.36	0.63	0.39	0.53	0.41	0.69	0.15	0.19	0.84	0.77	0.59	0.50
9.0	0.22	0.67	0.38	0.53	0.41	0.73	0.17	0.22	0.87	0.80	0.63	0.50
10.0	0.11	0.71	0.37	0.54	0.40	0.76	0.20	0.25	0.70	0.82	0.67	0.50
11.0	[illegible]	0.74	0.36	0.55	0.40	0.79	0.23	0.29	0.92	0.84	0.70	0.50
12.0	[illegible]	0.76	0.36	0.54	0.40	0.81	0.26	0.32	0.93	0.86	0.73	0.50
13.0	0.00	[illegible]	[illegible]	0.57	0.40	0.83	0.30	0.36	0.95	0.87	0.76	0.50
14.0	[illegible]	0.81	0.36	0.59	0.40	0.85	0.34	0.40	0.96	0.88	0.78	0.50
15.0	0.00	0.83	0.37	[illegible]	0.41	[illegible]	0.39	0.45	0.97	0.90	0.80	0.50
16.0	0.00	[illegible]	0.37	[illegible]	[illegible]	0.87	0.43	0.49	0.97	0.91	0.82	0.50
17.0	0.00	[illegible]	0.38	[illegible]	[illegible]	[illegible]	0.47	0.53	0.98	0.92	0.83	0.50
18.0	0.00	[illegible]	0.38	[illegible]	[illegible]	0.89	0.51	0.57	0.98	0.92	0.85	0.50
19.0	0.00	[illegible]	[illegible]	[illegible]	0.42	0.90	0.55	0.61	0.99	0.93	0.86	0.50
20.0	0.00	0.90	0.42	0.68	0.43	0.91	0.58	0.65	0.99	0.94	0.87	0.50

VARIATION K8 - TECHNOLOGICAL OPTIMISM

K.8 ALPHA VALUE MATRIX

		G 1	C 2	B 3	E 4	O 5	S 6	U 7	I 8	T 9	M 10	R 11	OW 12
G	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	3	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E	4	0.20	0.00	0.00	0.00	-0.20	0.00	0.00	-0.05	0.00	0.00	0.00	0.00
O	5	-0.10	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	8	-0.05	0.00	0.02	0.00	0.05	0.00	0.00	0.00	0.00	0.00	-0.10	0.00
T	9	0.40	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.00	0.00	-0.20	0.10
M	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R	11	-0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00
OW	12	0.00	0.20	0.10	0.00	0.00	0.10	0.00	0.00	0.10	0.20	0.40	0.00

BETA VALUE MATRIX

		G 1	C 2	B 3	E 4	O 5	S 6	U 7	I 8	T 9	M 10	R 11	OW 12
G	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	2	-0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	3	-0.05	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E	4	-0.25	0.20	0.00	0.00	-0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O	5	-0.05	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	6	-0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U	7	-0.05	0.00	0.00	0.00	0.05	0.00	0.05	0.10	0.00	0.00	0.00	0.00
I	8	0.00	0.00	0.00	0.00	0.15	0.00	0.30	0.00	0.30	0.00	-0.10	0.00
T	9	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	10	-0.10	0.00	0.00	0.00	0.10	0.10	0.10	0.00	0.00	0.00	0.00	0.00
R	11	0.00	0.10	-0.20	0.00	0.00	0.20	0.05	0.00	0.20	0.10	0.00	0.00
OW	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00

OUTPUT

TIME UNIT ↓	G 1	C 2	B 3	E 4	O 5	S 6	U 7	I 8	T 9	M 10	R 11	OW 12
1.0	0.90	0.30	0.50	0.50	0.50	0.30	0.10	0.10	0.50	0.50	0.20	0.50
2.0	0.91	0.37	0.52	0.52	0.48	0.32	0.14	0.14	0.53	0.53	0.23	0.50
3.0	0.90	0.38	0.52	0.51	0.49	0.36	0.21	0.18	0.57	0.57	0.24	0.50
4.0	0.90	0.42	0.53	0.54	0.52	0.40	0.30	0.24	0.61	0.60	0.24	0.50
5.0	0.89	0.45	0.54	0.58	0.54	0.44	0.41	0.31	0.64	0.63	0.24	0.50
6.0	0.87	0.49	0.56	0.62	0.57	0.46	0.53	0.37	0.67	0.66	0.24	0.50
7.0	0.85	0.52	0.58	0.65	0.60	0.48	0.63	0.44	0.69	0.68	0.23	0.50
8.0	0.84	0.55	0.61	0.69	0.63	0.50	0.73	0.51	0.71	0.71	0.21	0.50
9.0	0.83	0.57	0.63	0.72	0.65	0.52	0.80	0.58	0.72	0.73	0.20	0.50
10.0	0.82	0.60	0.66	0.75	0.66	0.53	0.85	0.63	0.73	0.74	0.18	0.50
11.0	0.81	0.62	0.68	0.77	0.68	0.54	0.89	0.69	0.74	0.76	0.16	0.50
12.0	0.81	0.64	0.70	0.79	0.69	0.55	0.92	0.73	0.76	0.78	0.15	0.50
13.0	0.81	0.67	0.73	0.81	0.69	0.56	0.94	0.77	0.76	0.79	0.13	0.50
14.0	0.81	0.69	0.75	0.82	0.70	0.57	0.96	0.81	0.77	0.81	0.12	0.50
15.0	0.82	0.71	0.77	0.84	0.70	0.58	0.97	0.84	0.78	0.82	0.10	0.50
16.0	0.83	0.73	0.78	0.85	0.69	0.59	0.97	0.86	0.79	0.83	0.09	0.50
17.0	0.84	0.75	0.80	0.87	0.69	0.60	0.98	0.88	0.80	0.84	0.08	0.50
18.0	0.85	0.76	0.82	0.88	0.68	0.61	0.99	0.90	0.80	0.86	0.07	0.50
19.0	0.86	0.78	0.83	0.89	0.62	0.63	0.99	0.92	0.81	0.87	0.06	0.50
20.0	0.87	0.80	0.84	0.87	0.67	0.64	0.99	0.93	0.82	0.88	0.05	0.50

APPENDIX C

Listing of Selected Coast Guard Vessels

The following figures present a listing of major Coast Guard vessels.* All vessels currently in service and/or anticipated are listed.

A vertical bar indicates a vessel's entry into service. Double vertical bars indicate the time during which a vehicle series entered service. For example, the individual vessels in the series Patrol Craft - Large, Series B entered service between 1961 and 1968.

A letter code indicates a vessel's entry status.

E - Expected
R - Requested
P - Planned
C - Under Construction

An X in a vessel number, e.g., WLB X10, indicates that the vessels in the series are sequentially numbered for the purposes of this report. These are not actual vessel numbers. Patrol Craft are not individually numbered in Jane's, so sequence numbers have been arbitrarily assigned, e.g., Series A-1, Series A-2, etc.

A solid horizontal line indicates past service life. A dashed line indicates expected service life, assuming a thirty-year service life.

* "Register of Cutters of the U.S. Coast Guard 1979", DOT COMDTINST M5441.5, also Jane's Fighting Ships, 1977-1978, John E. Moore, ed., (New York: Franklin Watts, Inc., 1978).

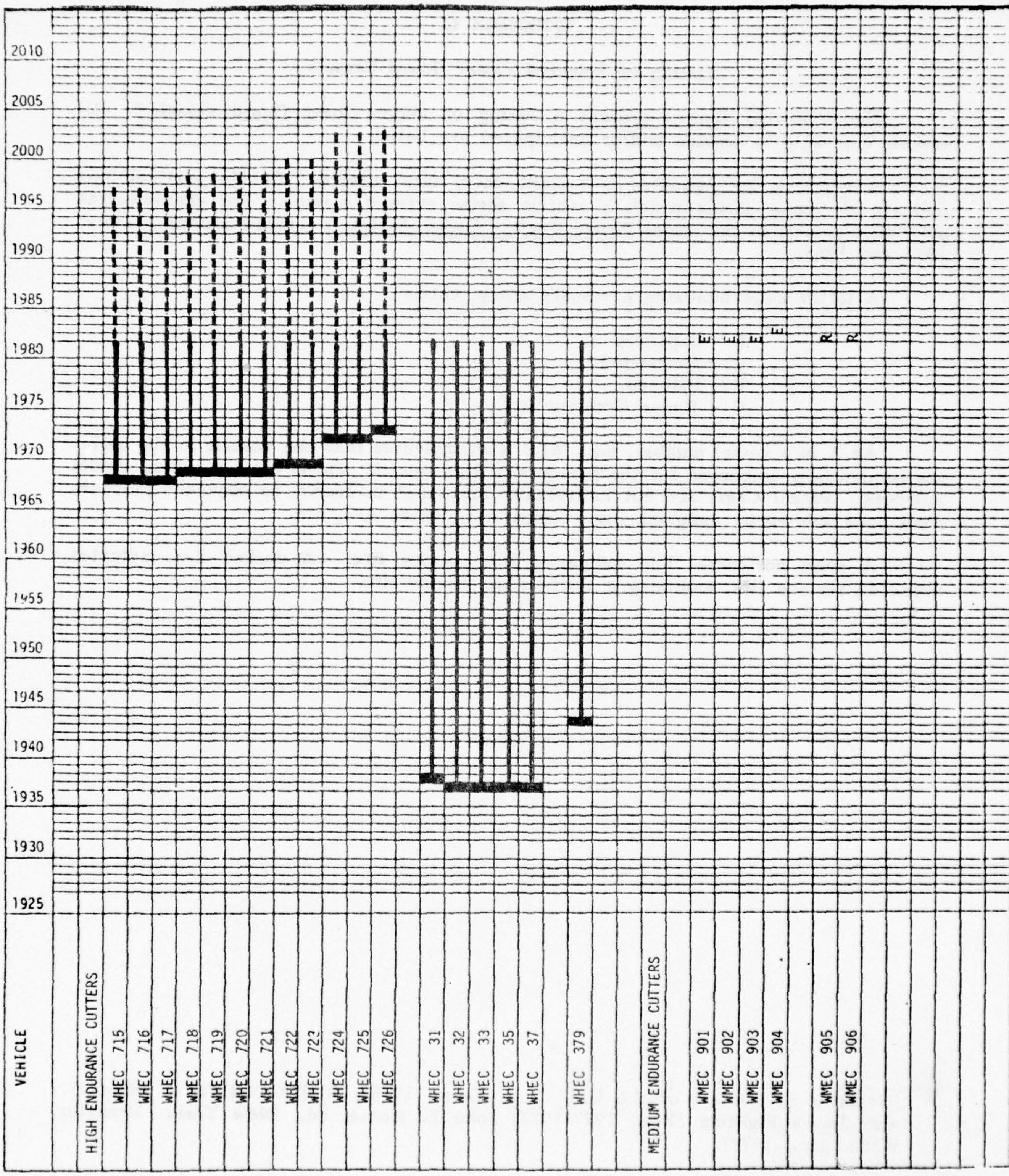

2010
2005
2000
1995
1990
1985
1980
1975
1970
1965
1960
1955
1950
1945
1940
1935
1930
1925
VEHICLE
HIGH ENDURANCE CUTTERS
WHEC 715
WHEC 716
WHEC 717
WHEC 718
WHEC 719
WHEC 720
WHEC 721
WHEC 722
WHEC 723
WHEC 724
WHEC 725
WHEC 726
WHEC 31
WHEC 32
WHEC 33
WHEC 35
WHEC 37
WHEC 379
MEDIUM ENDURANCE CUTTERS
WMEC 901
WMEC 902
WMEC 903
WMEC 904
WMEC 905
WMEC 906

Figure C-1

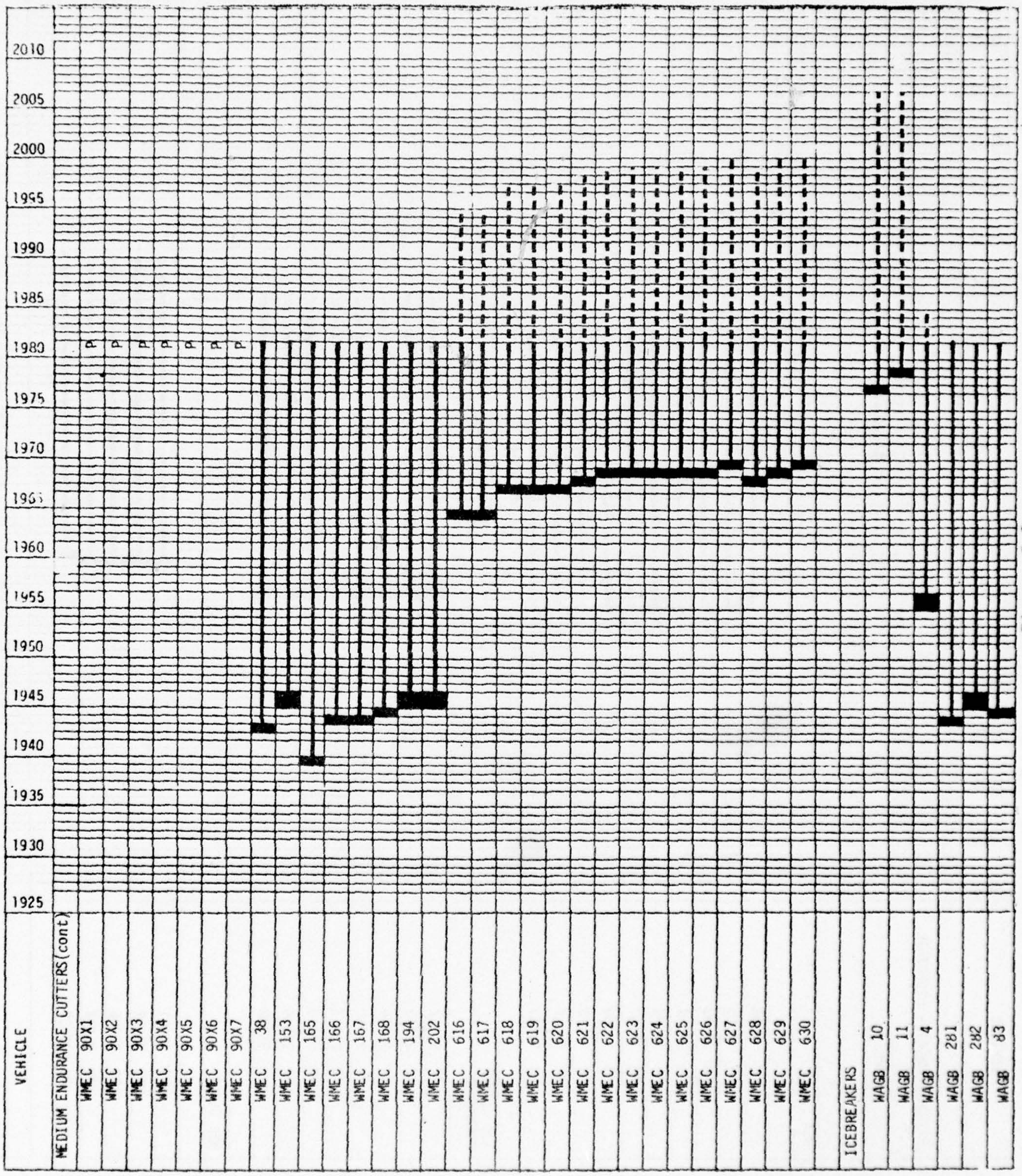

2010
2005
2000
1995
1990
1985
1980
1975
1970
1965
1960
1955
1950
1945
1940
1935
1930
1925
VEHICLE
MEDIUM ENDURANCE CUTTERS (cont)
WMEC 90X1
WMEC 90X2
WMEC 90X3
WMEC 90X4
WMEC 90X5
WMEC 90X6
WMEC 90X7
WMEC 38
WMEC 153
WMEC 165
WMEC 166
WMEC 167
WMEC 168
WMEC 194
WMEC 202
WMEC 616
WMEC 617
WMEC 618
WMEC 619
WMEC 620
WMEC 621
WMEC 622
WMEC 623
WMEC 624
WMEC 625
WMEC 626
WMEC 627
WMEC 628
WMEC 629
WMEC 630
ICEBREAKERS
WAGB 10
WAGB 11
WAGB 4
WAGB 281
WAGB 282
WAGB 83

Figure C-2

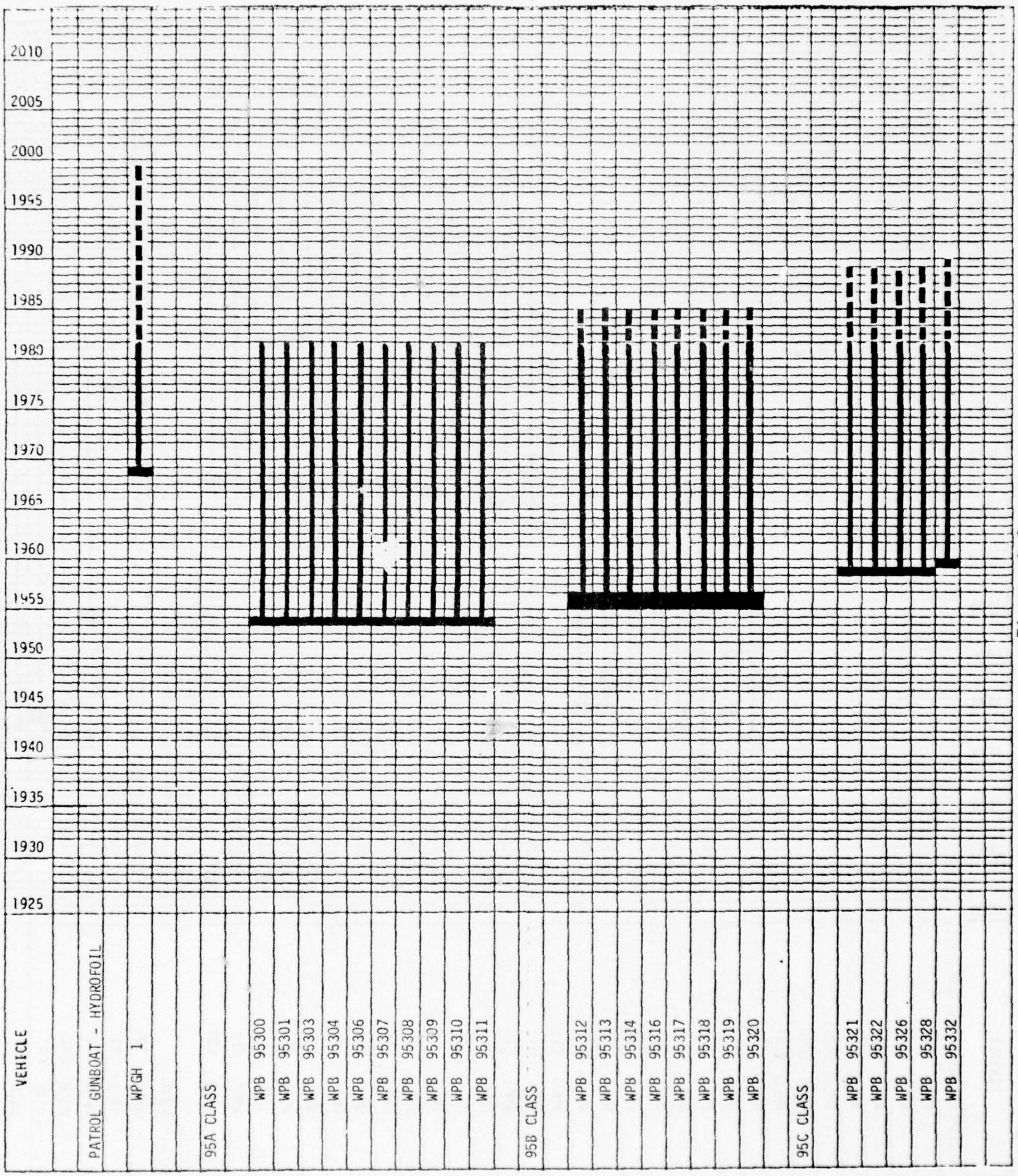

VEHICLE
PATROL GUNBOAT - HYDROFOIL
WPGH 1
95A CLASS
WPB 95300
WPB 95301
WPB 95303
WPB 95304
WPB 95306
WPB 95307
WPB 95308
WPB 95309
WPB 95310
WPB 95311
95B CLASS
WPB 95312
WPB 95313
WPB 95314
WPB 95316
WPB 95317
WPB 95318
WPB 95319
WPB 95320
95C CLASS
WPB 95321
WPB 95322
WPB 95326
WPB 95328
WPB 95332
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

Figure C-3

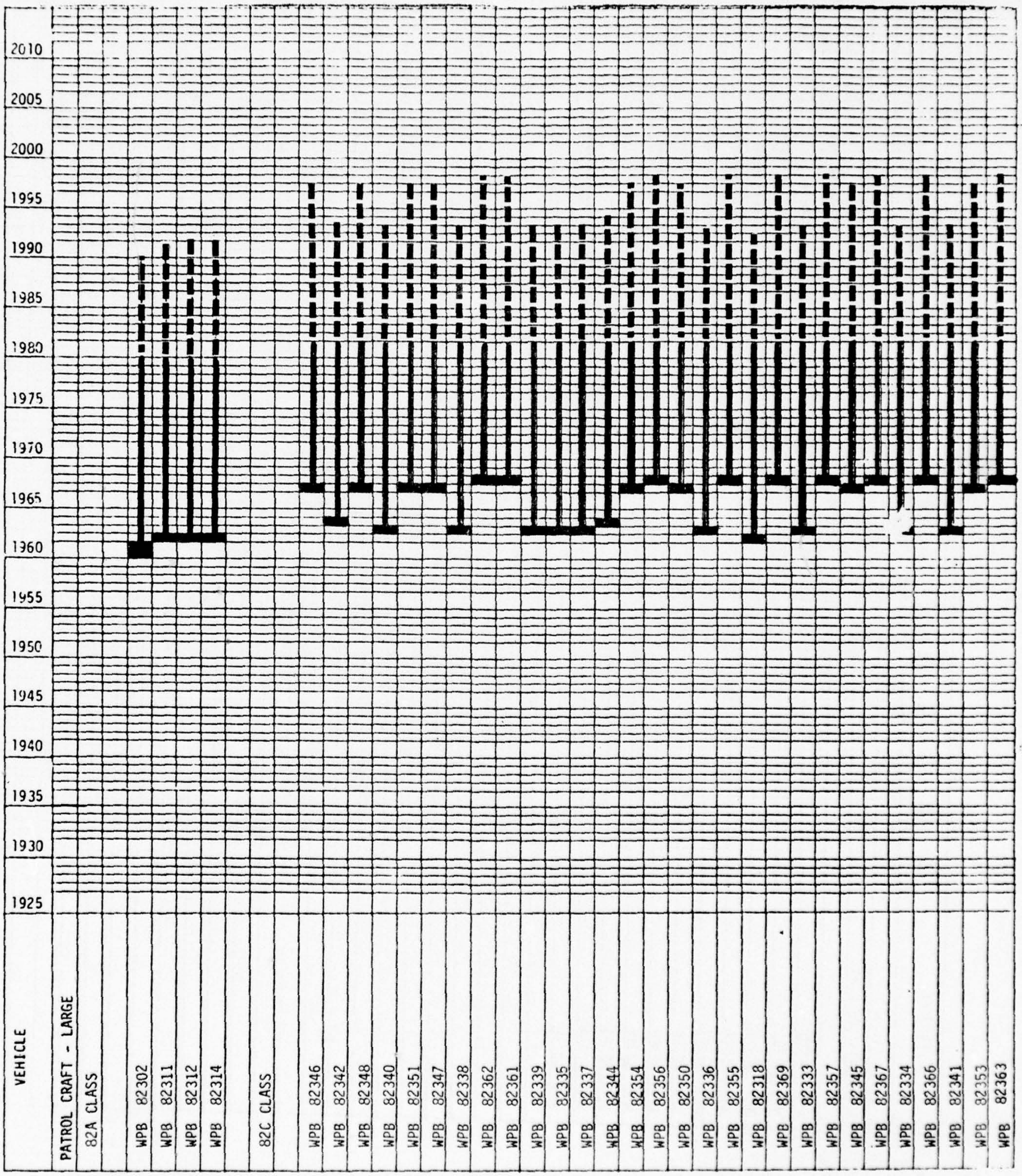

VEHICLE
PATROL CRAFT - LARGE
82A CLASS
WPB 82302
WPB 82311
WPB 82312
WPB 82314
82C CLASS
WPB 82346
WPB 82342
WPB 82348
WPB 82340
WPB 82351
WPB 82347
WPB 82338
WPB 82362
WPB 82361
WPB 82339
WPB 82335
WPB 82337
WPB 82344
WPB 82354
WPB 82356
WPB 82350
WPB 82336
WPB 82355
WPB 82318
WPB 82369
WPB 82333
WPB 82357
WPB 82345
WPB 82367
WPB 82334
WPB 82366
WPB 82341
WPB 82353
WPB 82363
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

Figure C-4

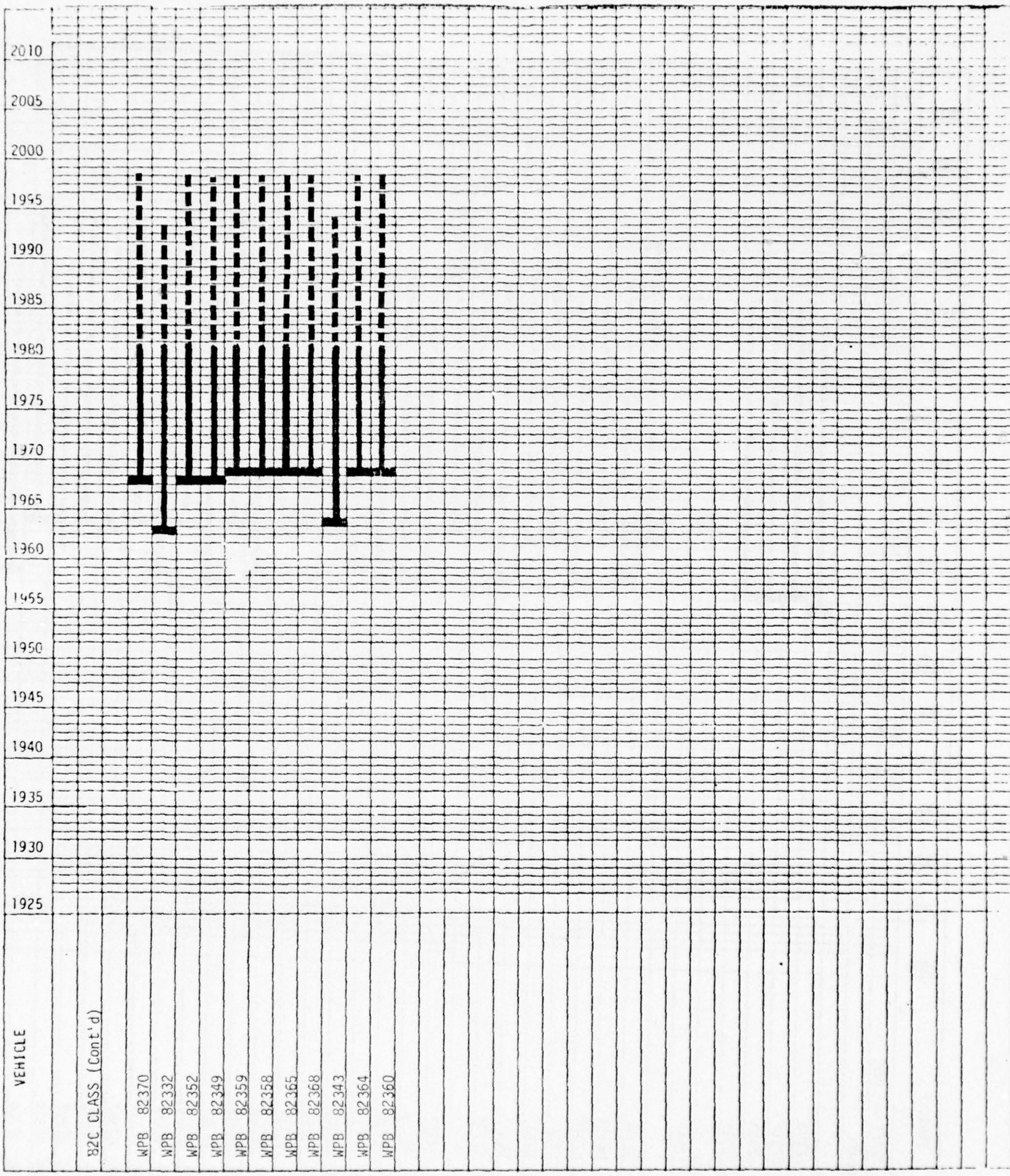


Figure C-4 (cont.)

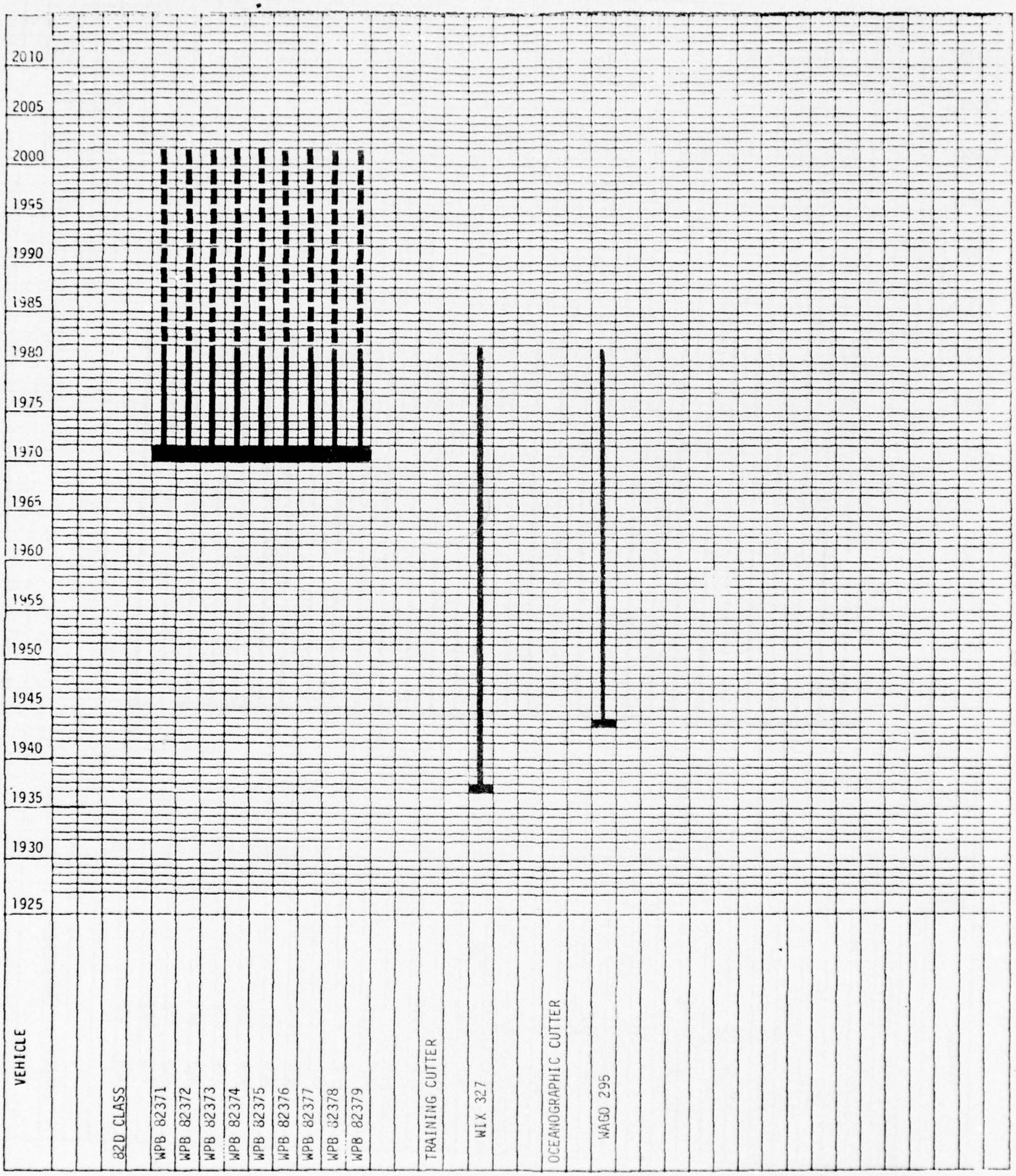

2010
2005
2000
1995
1990
1985
1980
1975
1970
1965
1960
1955
1950
1945
1940
1935
1930
1925
VEHICLE
82D CLASS
WPB 82371
WPB 82372
WPB 82373
WPB 82374
WPB 82375
WPB 82376
WPB 82377
WPB 82378
WPB 82379
TRAINING CUTTER
WIX 327
OCEANOGRAPHIC CUTTER
WAGO 295

Figure C-5

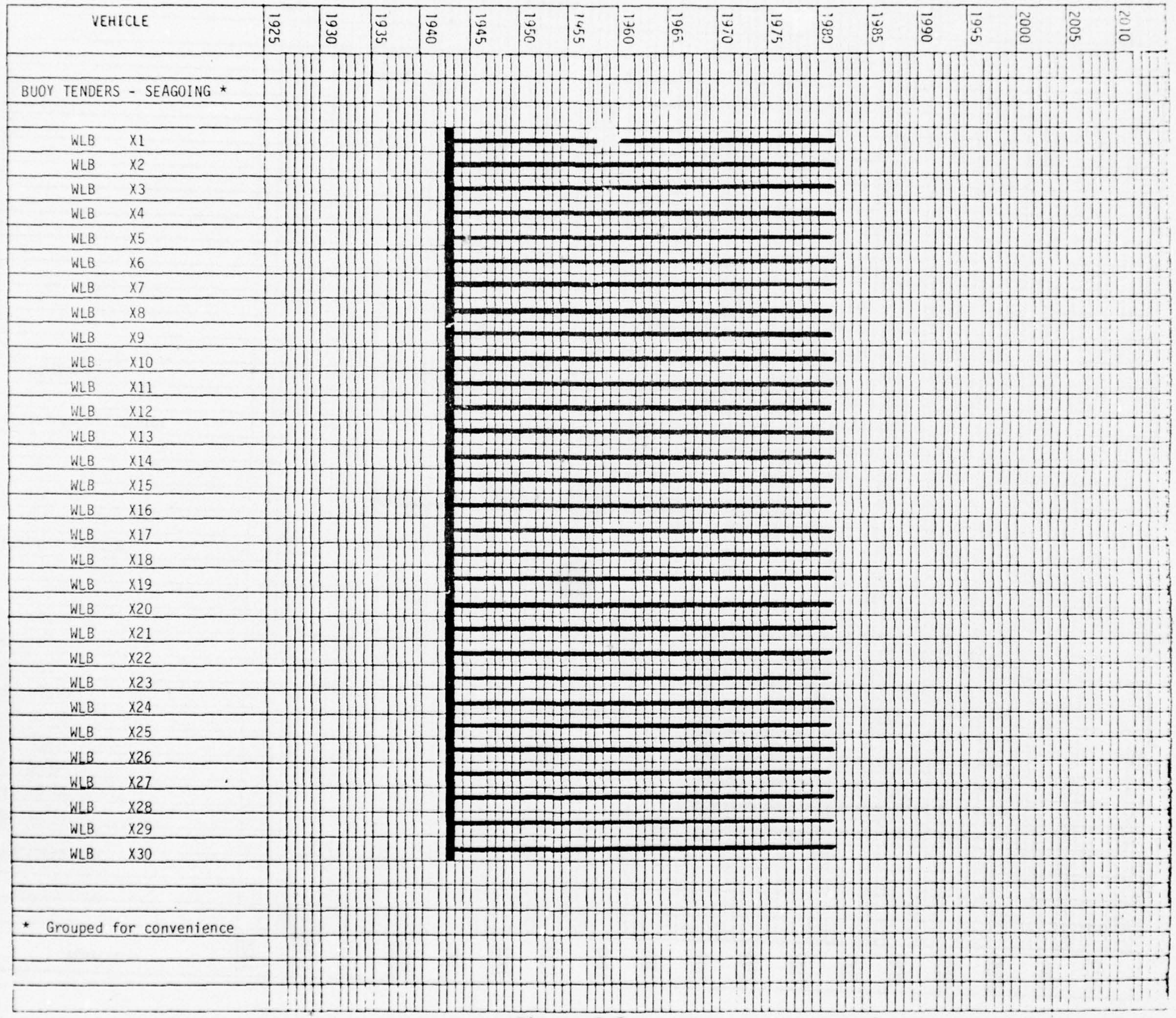

VEHICLE
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
BUOY TENDERS - SEAGOING *
WLB X1
WLB X2
WLB X3
WLB X4
WLB X5
WLB X6
WLB X7
WLB X8
WLB X9
WLB X10
WLB X11
WLB X12
WLB X13
WLB X14
WLB X15
WLB X16
WLB X17
WLB X18
WLB X19
WLB X20
WLB X21
WLB X22
WLB X23
WLB X24
WLB X25
WLB X26
WLB X27
WLB X28
WLB X29
WLB X30
* Grouped for convenience

Figure C-6

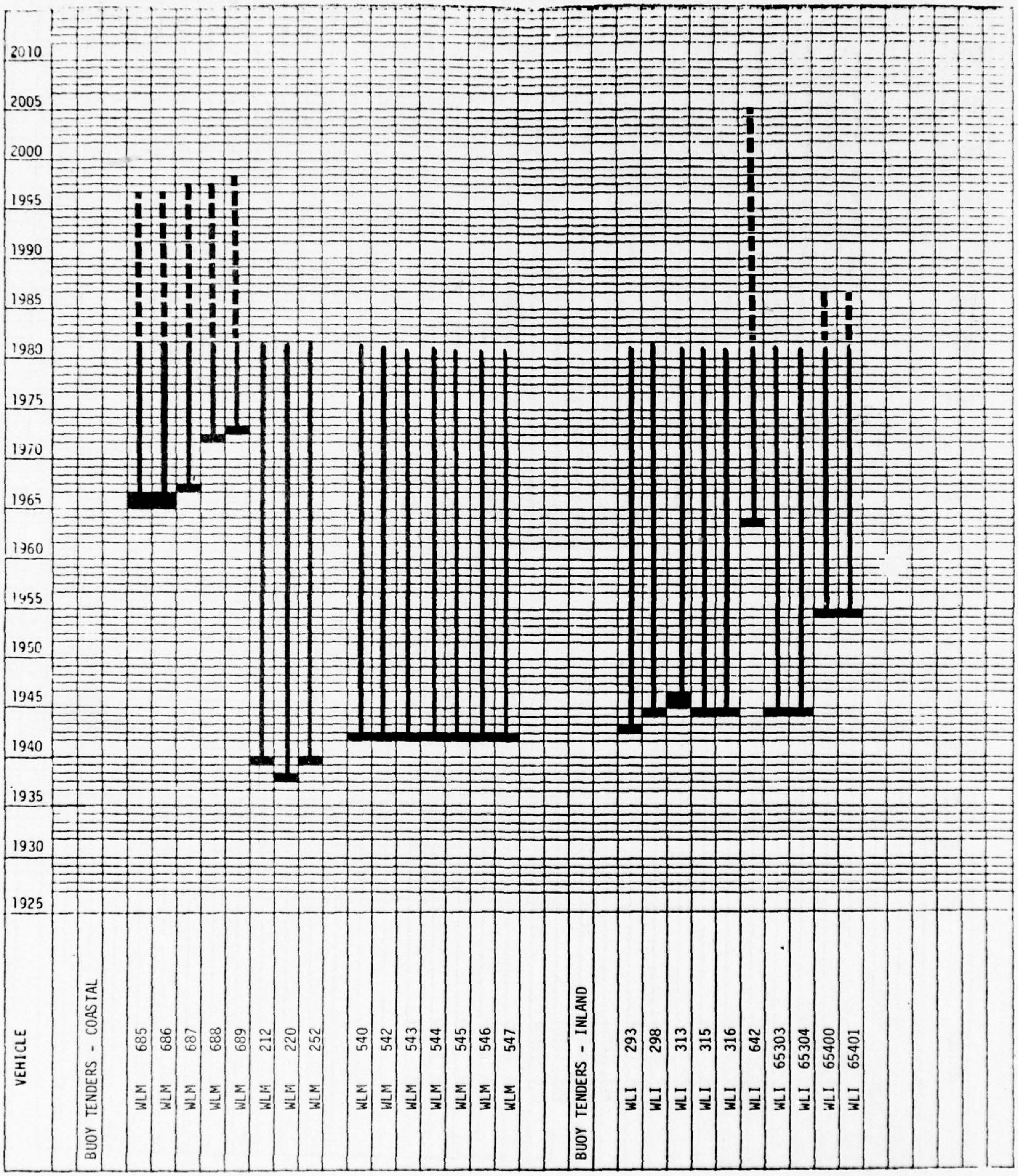
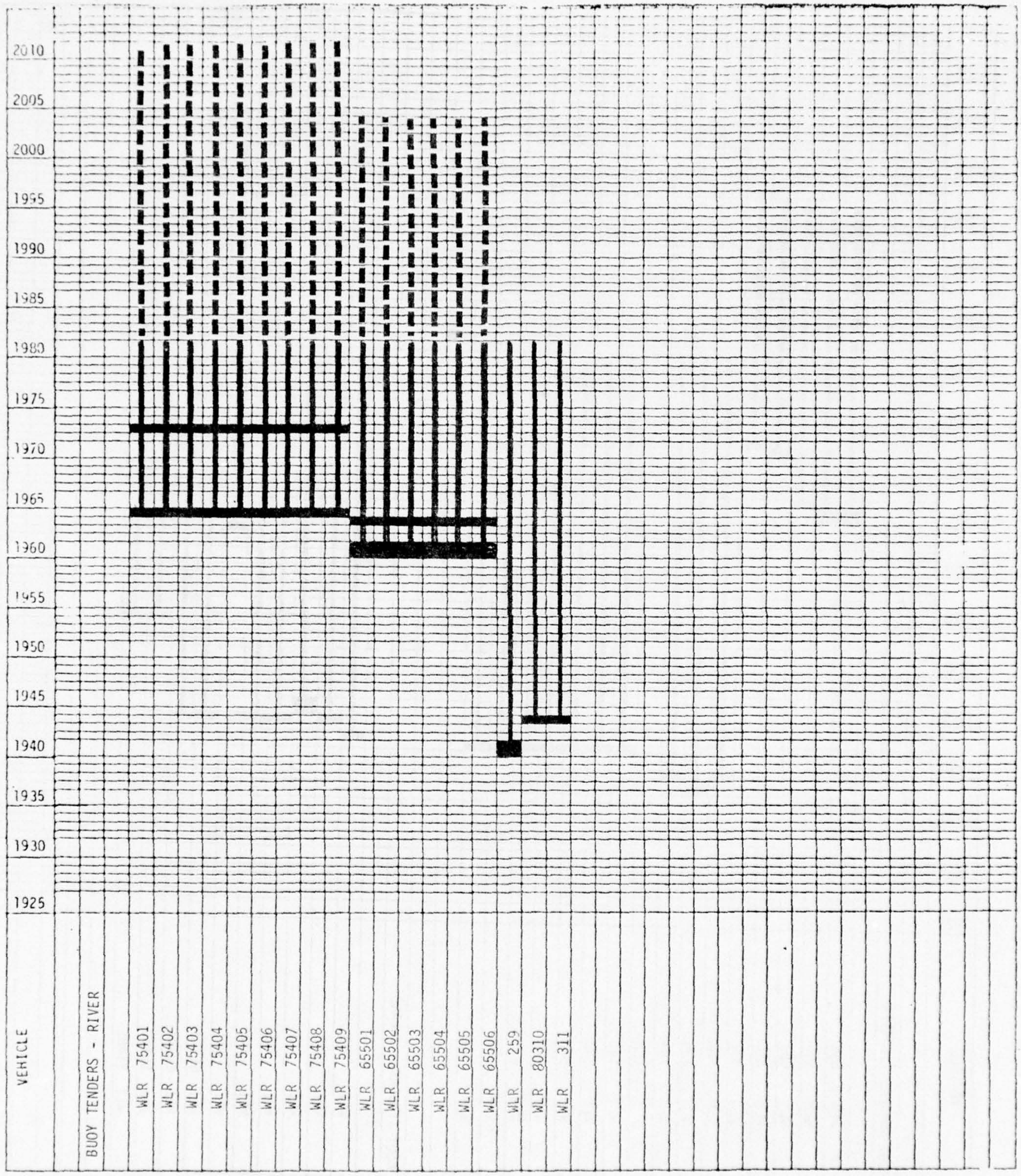
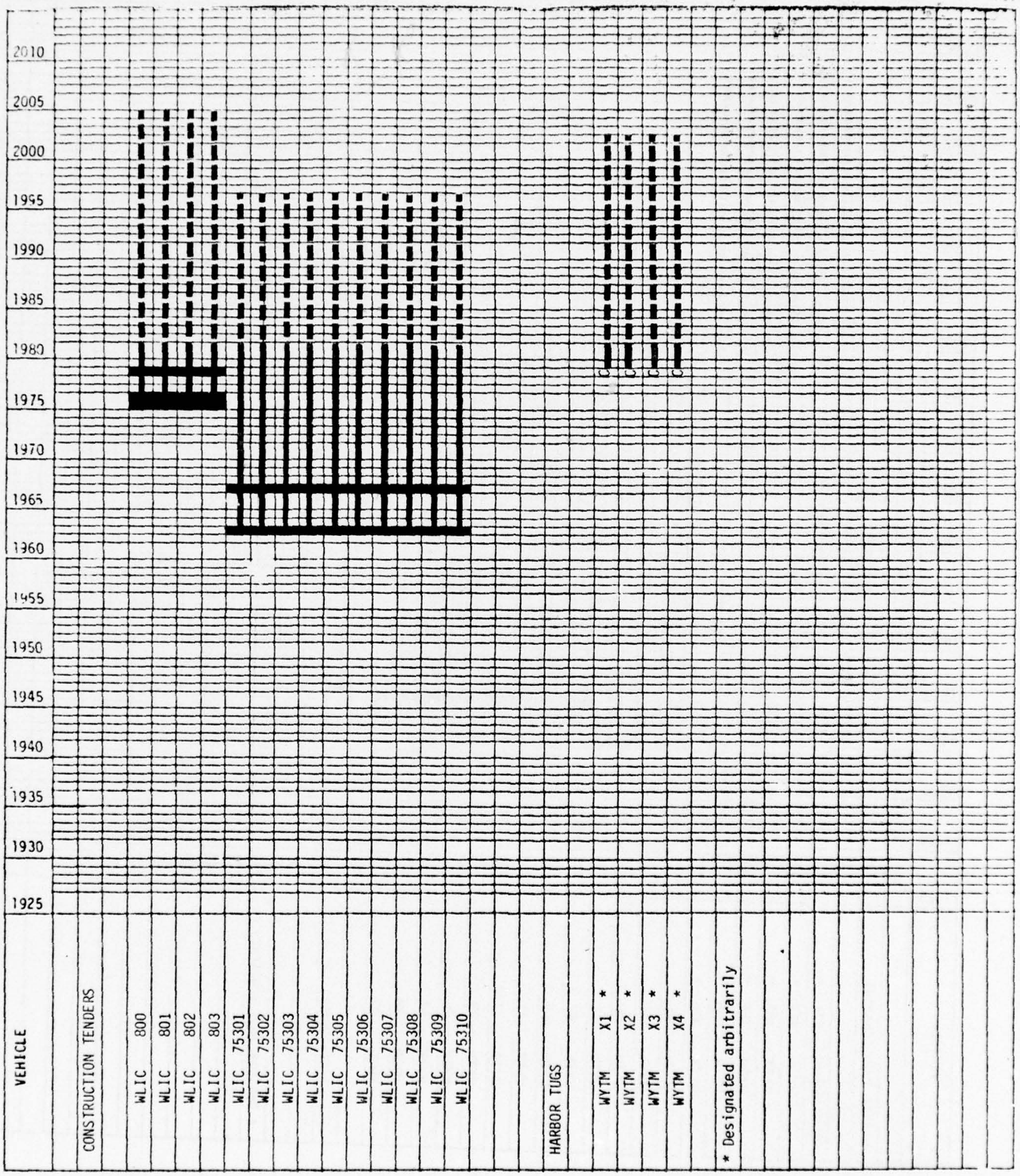

2010
2005
2000
1995
1990
1985
1980
1975
1970
1965
1960
1955
1950
1945
1940
1935
1930
1925
VEHICLE
BUOY TENDERS - COASTAL
WLM 685
WLM 686
WLM 687
WLM 688
WLM 689
WLM 212
WLM 220
WLM 252
WLM 540
WLM 542
WLM 543
WLM 544
WLM 545
WLM 546
WLM 547
BUOY TENDERS - INLAND
WLI 293
WLI 298
WLI 313
WLI 315
WLI 316
WLI 642
WLI 65303
WLI 65304
WLI 65400
WLI 65401

Figure C-7



2010
2005
2000
1995
1990
1985
1980
1975
1970
1965
1960
1955
1950
1945
1940
1935
1930
1925
VEHICLE
BUOY TENDERS - RIVER
WLR 75401
WLR 75402
WLR 75403
WLR 75404
WLR 75405
WLR 75406
WLR 75407
WLR 75408
WLR 75409
WLR 65501
WLR 65502
WLR 65503
WLR 65504
WLR 65505
WLR 65506
WLR 259
WLR 80310
WLR 311

Figure C-8



2010
2005
2000
1995
1990
1985
1980
1975
1970
1965
1960
1955
1950
1945
1940
1935
1930
1925
VEHICLE
CONSTRUCTION TENDERS
WLIC 800
WLIC 801
WLIC 802
WLIC 803
WLIC 75301
WLIC 75302
WLIC 75303
WLIC 75304
WLIC 75305
WLIC 75306
WLIC 75307
WLIC 75308
WLIC 75309
WLIC 75310
HARBOR TUGS
WYTM X1 *
WYTM X2 *
WYTM X3 *
WYTM X4 *
* Designated arbitrarily

Figure C-9

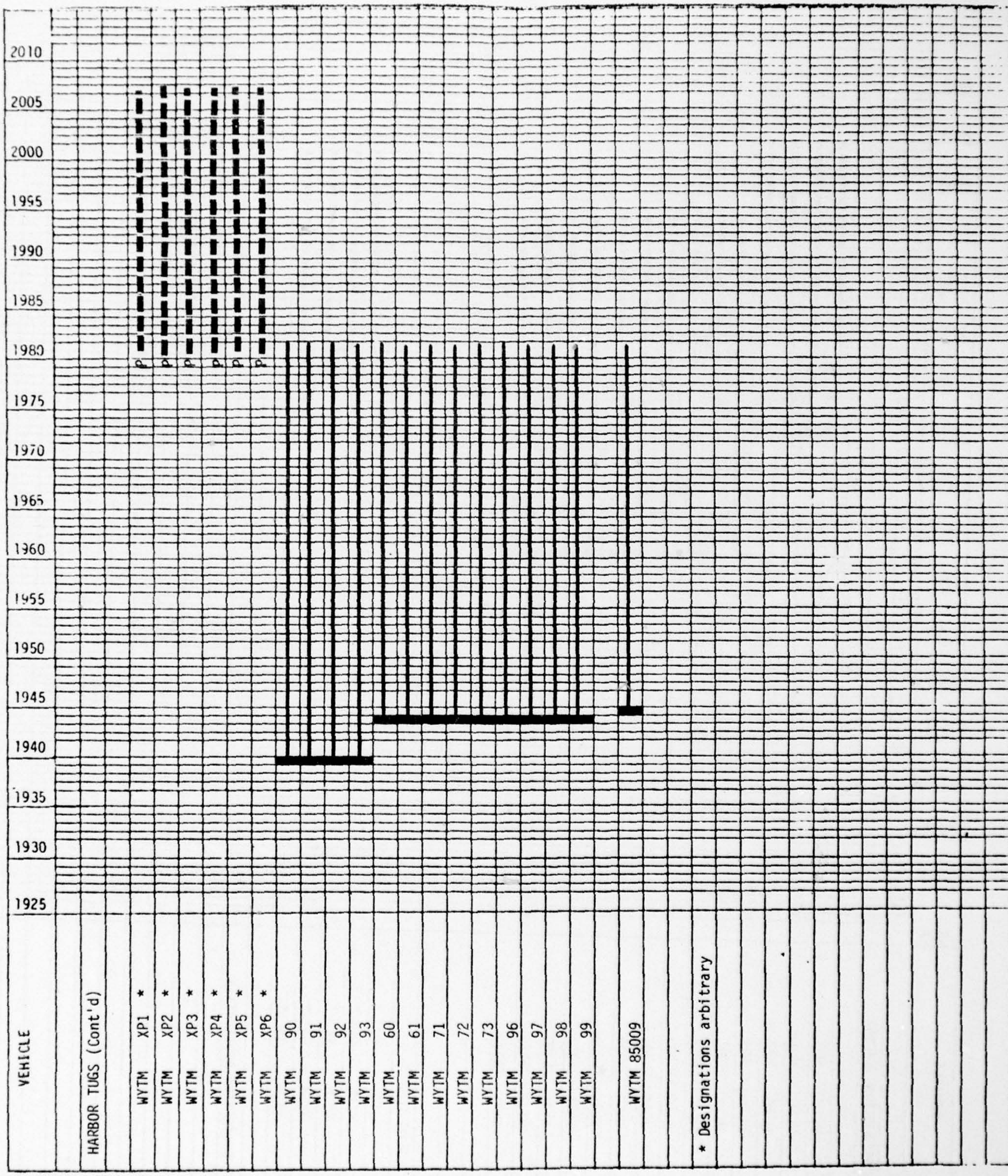
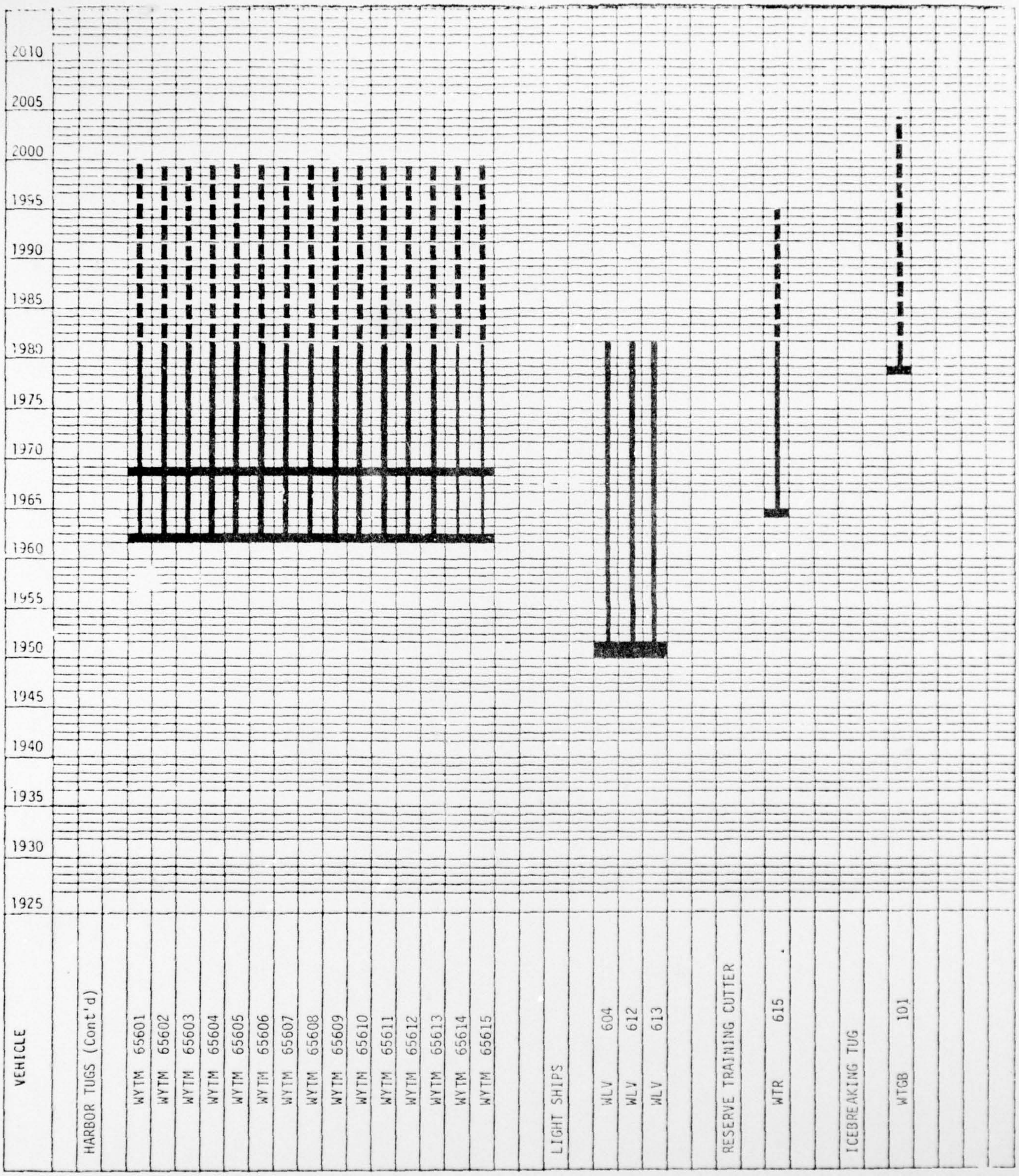

2010
2005
2000
1995
1990
1985
1980
1975
1970
1965
1960
1955
1950
1945
1940
1935
1930
1925
VEHICLE
HARBOR TUGS (Cont'd)
WYTM XP1 *
WYTM XP2 *
WYTM XP3 *
WYTM XP4 *
WYTM XP5 *
WYTM XP6 *
WYTM 90
WYTM 91
WYTM 92
WYTM 93
WYTM 60
WYTM 61
WYTM 71
WYTM 72
WYTM 73
WYTM 96
WYTM 97
WYTM 98
WYTM 99
WYTM 85009
* Designations arbitrary
P
P
P
P
P
P

Figure C-10



2010
2005
2000
1995
1990
1985
1980
1975
1970
1965
1960
1955
1950
1945
1940
1935
1930
1925
VEHICLE
HARBOR TUGS (Cont'd)
WYTM 65601
WYTM 65602
WYTM 65603
WYTM 65604
WYTM 65605
WYTM 65606
WYTM 65607
WYTM 65608
WYTM 65609
WYTM 65610
WYTM 65611
WYTM 65612
WYTM 65613
WYTM 65614
WYTM 65615
LIGHT SHIPS
WLV 604
WLV 612
WLV 613
RESERVE TRAINING CUTTER
WTR 615
ICEBREAKING TUG
WTGB 101

Figure C-11

APPENDIX D

Mission Analysis Details

1. Mission Flow Diagrams

Sample mission flow diagrams were discussed in Chapter III. Each diagram represents an attempt to assimilate and integrate all the information relating to specific patrol, incident response, and non-patrol routine operations that was derived from the program/activity and activity/vehicle analyses. The diagrams themselves are self-explanatory. They do not (and obviously could not) depict all possible ways of responding to incidents of a certain type or for carrying out certain patrols. However, they do give a representative cross section of the relevant parameters, vehicles, and tactical combinations. They show how various vehicles are important for certain operations, and what possible points of substitution there are for other vehicles or non-vehicle technologies. Further, they provide a template for discussing the operational viability of any additional advanced design vehicles, non-vehicle technologies, and tactical approaches, which are not specifically discussed in the given diagrams. For example, the potential use of a system of remote controlled drone aircraft for patrol of the coastlines can be made more explicit using the patrol mission flow diagrams.

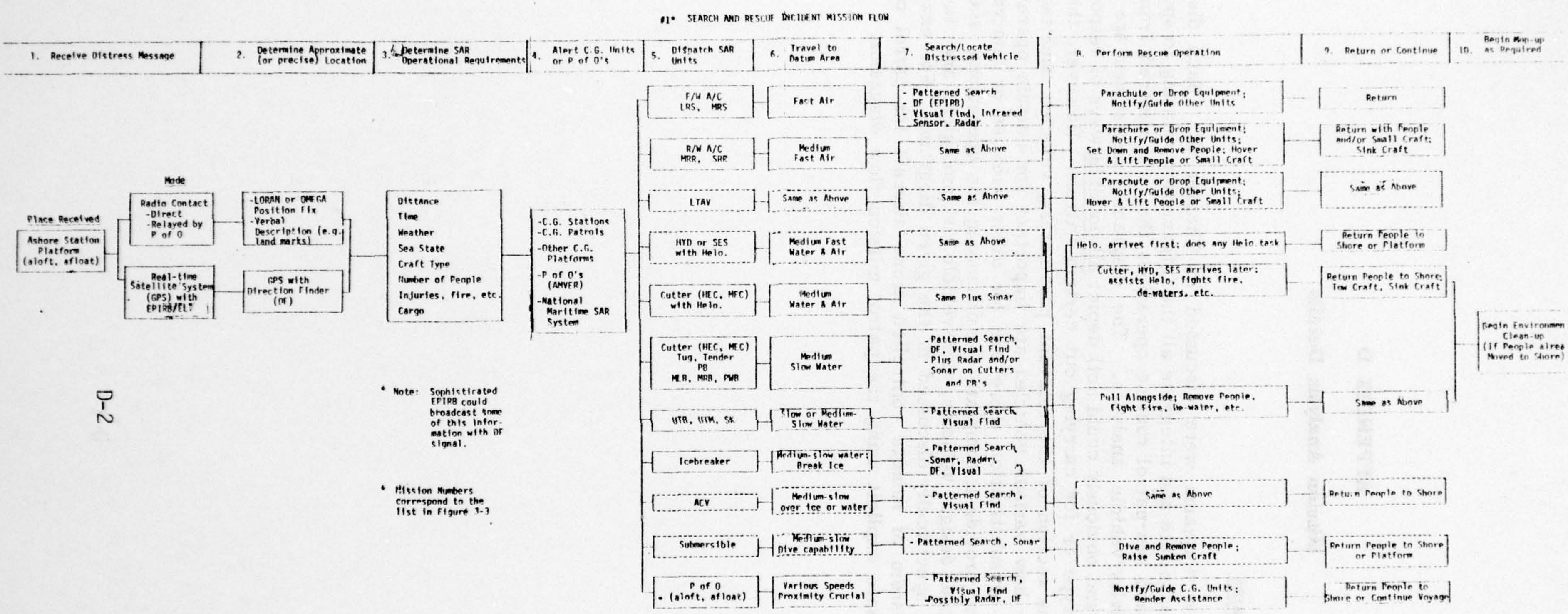

#1* SEARCH AND RESCUE INCIDENT MISSION FLOW
1. Receive Distress Message
2. Determine Approximate (or precise) Location
3. Determine SAR Operational Requirements
4. Alert C.G. Units or P of O's
5. Dispatch SAR Units
6. Travel to Datum Area
7. Search/Locate Distressed Vehicle
8. Perform Rescue Operation
9. Return or Continue
10. Begin Mop-up as Required
Place Received
Ashore Station Platform (aloft, afloat)
Mode
Radio Contact -Direct -Relayed by P of O
Real-time Satellite System (GPS) with EPIRB/ELT
-LORAN or OMEGA Position Fix -Verbal Description (e.g. land marks)
GPS with Direction Finder (DF)
Distance
Time
Weather
Sea State
Craft Type
Number of People
Injuries, fire, etc.
Cargo
-C.G. Stations -C.G. Patrols -Other C.G. Platforms -P of O's (AMVER) -National Maritime SAR System
F/W A/C LRS, MRS
R/W A/C MRR, SRR
LTAV
HYD or SES with Helo.
Cutter (HEC, MEC) with Helo.
Cutter (HEC, MEC) Tug, Tender PB MLB, MRB, PWB
UTB, UIM, SK
Icebreaker
ACV
Submersible
P of O * (aloft, afloat)
Fast Air
Medium Fast Air
Same as Above
Medium Fast Water & Air
Medium Water & Air
Medium Slow Water
Slow or Medium-Slow Water
Medium-slow water; Break Ice
Medium-slow over ice or water
Medium-slow Dive capability
Various Speeds Proximity Crucial
- Patterned Search - DF (EPIRB) - Visual Find, Infrared Sensor, Radar
Same as Above
Same as Above
Same as Above
Same Plus Sonar
- Patterned Search, DF, Visual Find - Plus Radar and/or Sonar on Cutters and PB's
- Patterned Search, Visual Find
- Patterned Search, -Sonar, Radar, DF, Visual
- Patterned Search, Visual Find
- Patterned Search, Sonar
- Patterned Search, Visual Find -Possibly Radar, DF
Parachute or Drop Equipment; Notify/Guide Other Units
Parachute or Drop Equipment; Notify/Guide Other Units; Set Down and Remove People; Hover & Lift People or Small Craft
Parachute or Drop Equipment; Notify/Guide Other Units; Hover & Lift People or Small Craft
Helo. arrives first; does any Helo. task
Cutter, HYD, SES arrives later; assists Helo, fights fire, de-waters, etc.
Pull Alongside; Remove People, Fight Fire, De-water, etc.
Same as Above
Dive and Remove People; Raise Sunken Craft
Notify/Guide C.G. Units; Render Assistance
Return
Return with People and/or Small Craft; Sink Craft
Same as Above
Return People to Shore or Platform
Return People to Shore; Tow Craft, Sink Craft
Same as Above
Return People to Shore
Return People to Shore or Platform
Return People to Shore or Continue Voyage
Begin Environmen Clean-up (If People alrea Moved to Shore)
* Note: Sophisticated EPIRB could broadcast some of this information with DF signal.
* Mission Numbers correspond to the list in Figure 3-3

FIGURE D-1

#2 LAW ENFORCEMENT INCIDENT MISSION FLOW
(High Seas: Fisheries)

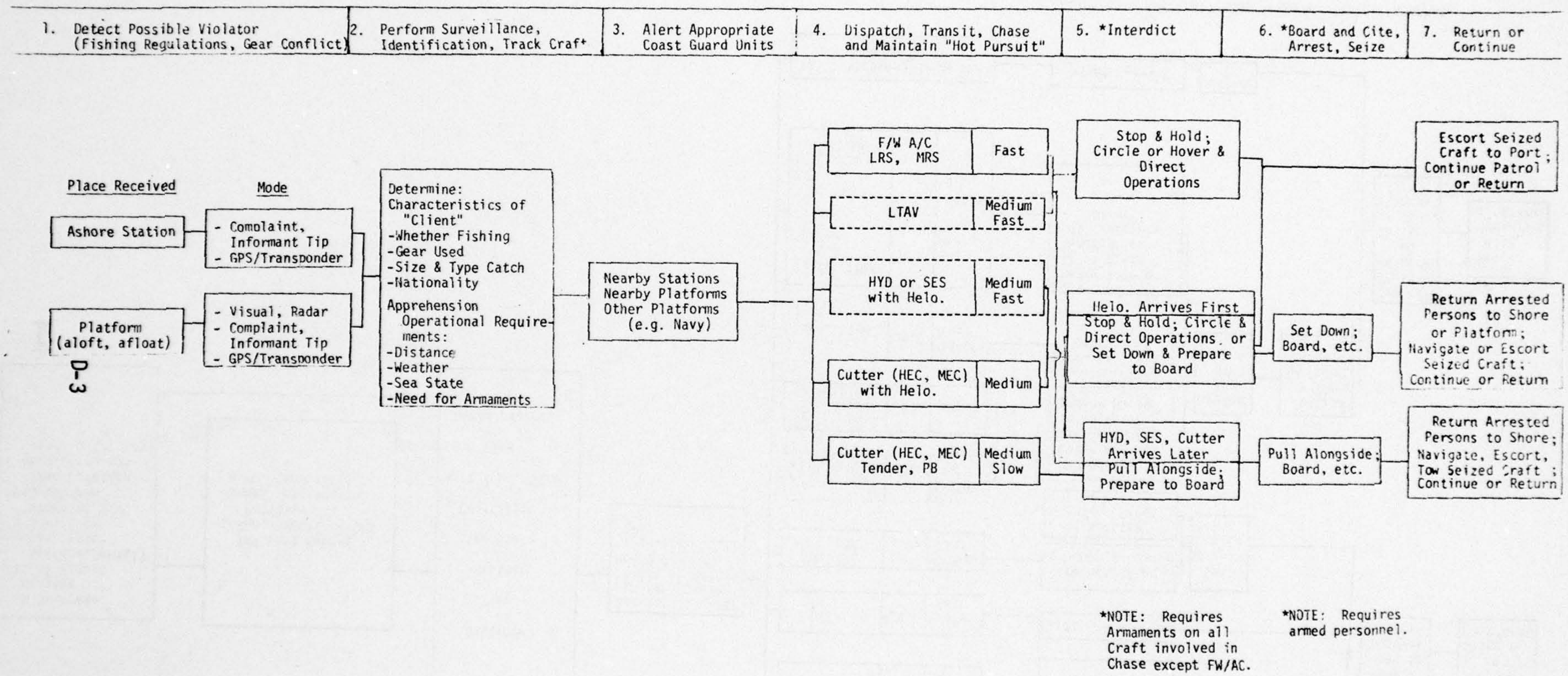
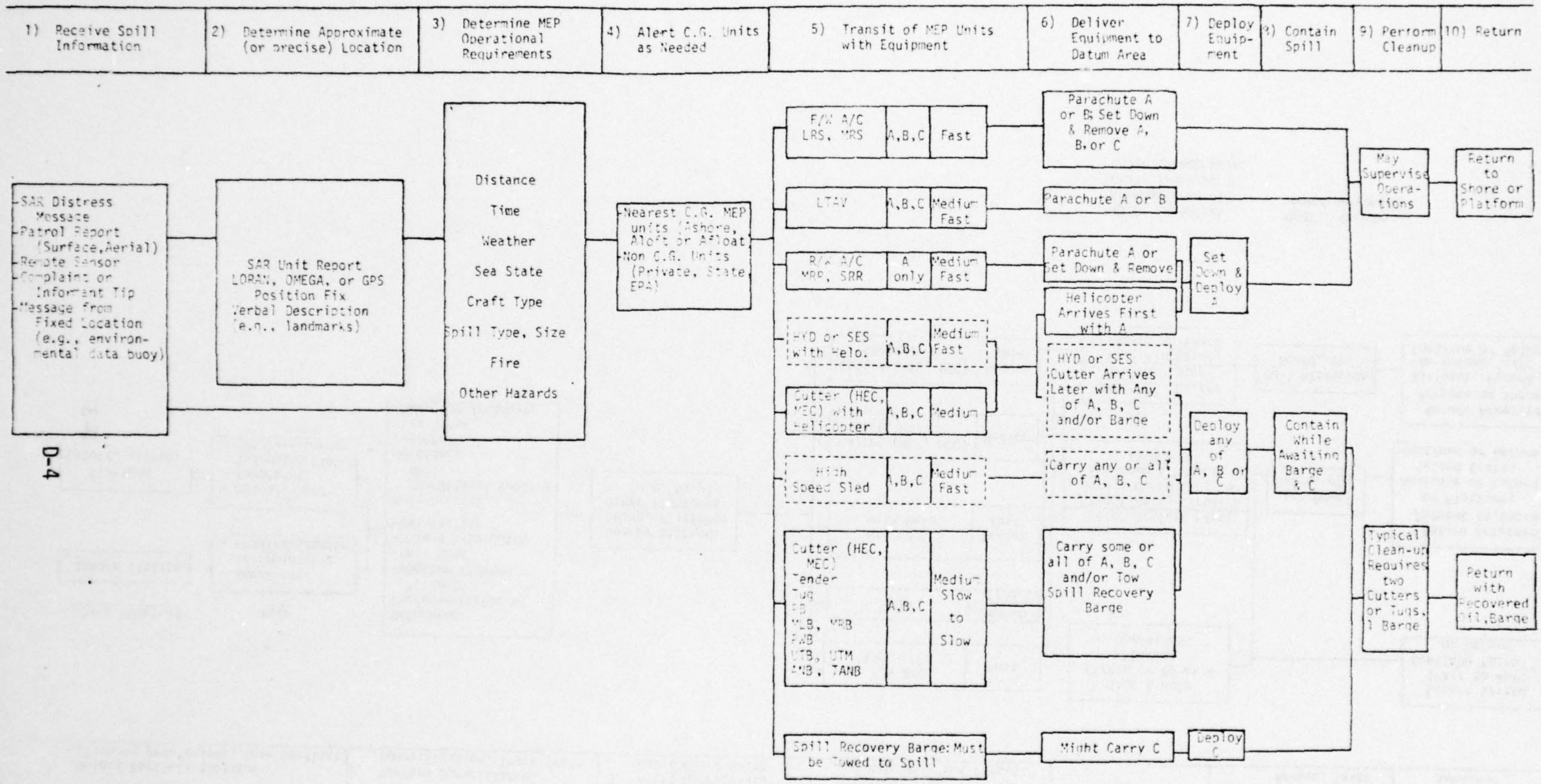


FIGURE D-2

#4 MARINE ENVIRONMENTAL PROTECTION INCIDENT MISSION FLOW (OIL OR CHEMICAL SPILL)



A = Air Deliverable Anti-pollution Transfer System (ADAPTS)
B = High Seas Containment Device
C = Oil Recovery Devices (typical clean-up requires two)

FIGURE D-3

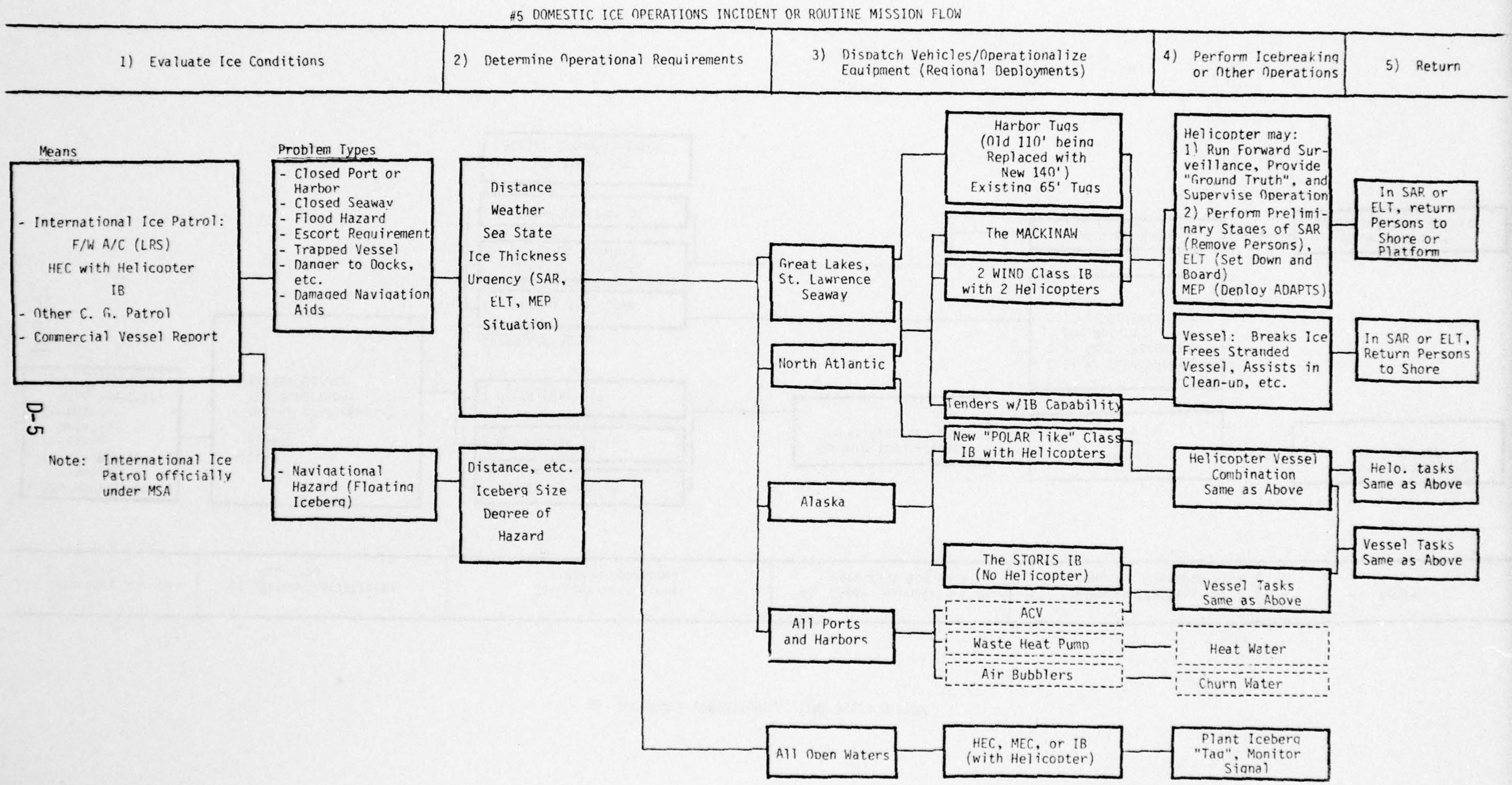

#5 DOMESTIC ICE OPERATIONS INCIDENT OR ROUTINE MISSION FLOW
1) Evaluate Ice Conditions
2) Determine Operational Requirements
3) Dispatch Vehicles/Operationalize Equipment (Regional Deployments)
4) Perform Icebreaking or Other Operations
5) Return
Means
- International Ice Patrol: F/W A/C (LRS) HEC with Helicopter IB
- Other C. G. Patrol
- Commercial Vessel Report
Note: International Ice Patrol officially under MSA
Problem Types
- Closed Port or Harbor
- Closed Seaway
- Flood Hazard
- Escort Requirement
- Trapped Vessel
- Danger to Docks, etc.
- Damaged Navigation Aids
- Navigational Hazard (Floating Iceberg)
Distance Weather Sea State Ice Thickness Urgency (SAR, ELT, MEP Situation)
Distance, etc. Iceberg Size Degree of Hazard
Great Lakes, St. Lawrence Seaway
North Atlantic
Alaska
All Ports and Harbors
All Open Waters
Harbor Tugs (Old 110' being Replaced with New 140') Existing 65' Tugs
The MACKINAW
2 WIND Class IB with 2 Helicopters
Tenders w/IB Capability
New "POLAR like" Class IB with Helicopters
The STORIS IB (No Helicopter)
ACV
Waste Heat Pump
Air Bubblers
HEC, MEC, or IB (with Helicopter)
Helicopter may: 1) Run Forward Surveillance, Provide "Ground Truth", and Supervise Operation 2) Perform Preliminary Stages of SAR (Remove Persons), ELT (Set Down and Board) MEP (Deploy ADAPTS)
Vessel: Breaks Ice Frees Stranded Vessel, Assists in Clean-up, etc.
Helicopter Vessel Combination Same as Above
Vessel Tasks Same as Above
Heat Water
Churn Water
Plant Iceberg "Tag", Monitor Signal
In SAR or ELT, return Persons to Shore or Platform
In SAR or ELT, Return Persons to Shore
Helo. tasks Same as Above
Vessel Tasks Same as Above

FIGURE D-4

#6 POLAR ICE OPERATIONS ROUTINE MISSION FLOW

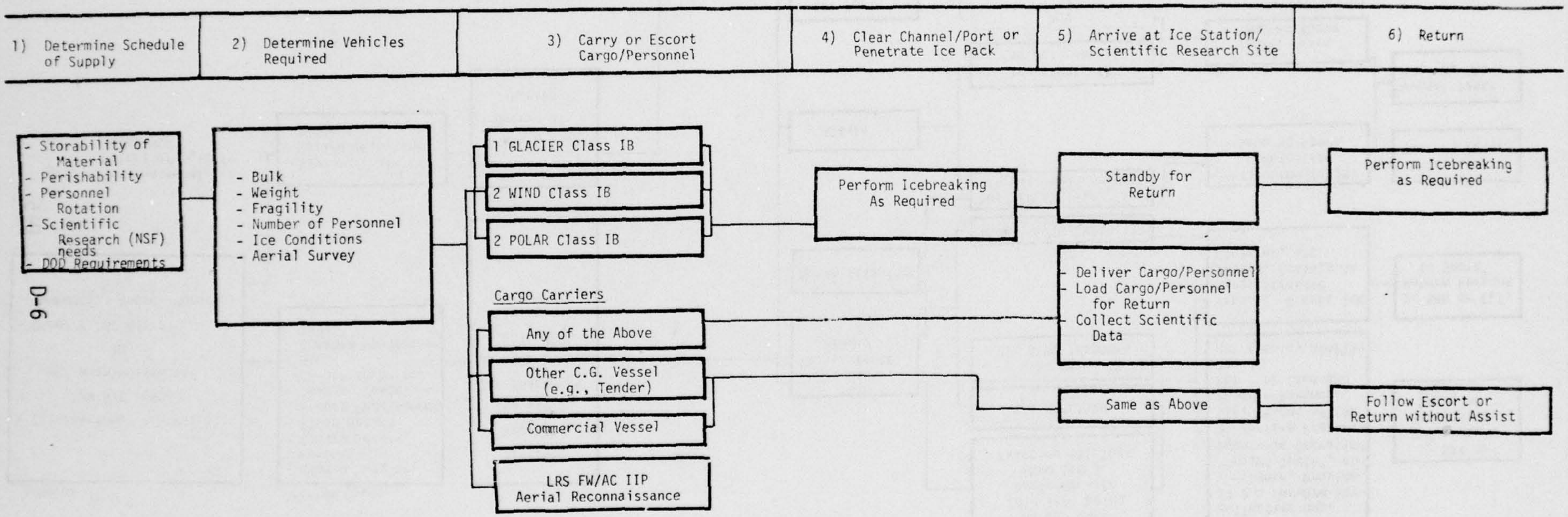


FIGURE D-5

#7 PATROL: GENERAL MISSION ANALYSIS

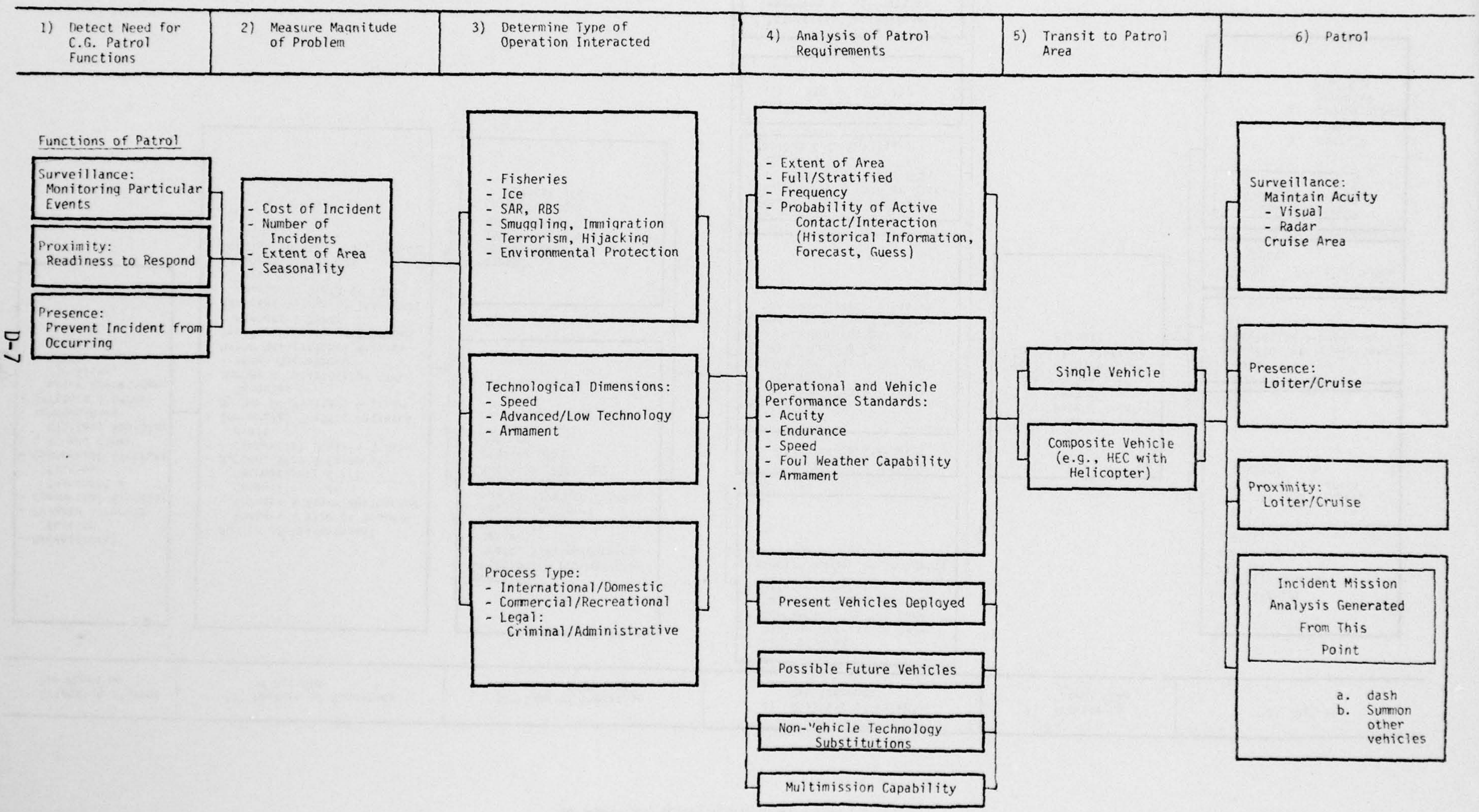


FIGURE D-6

#8 SEARCH AND RESCUE PATROL MISSION FLOW

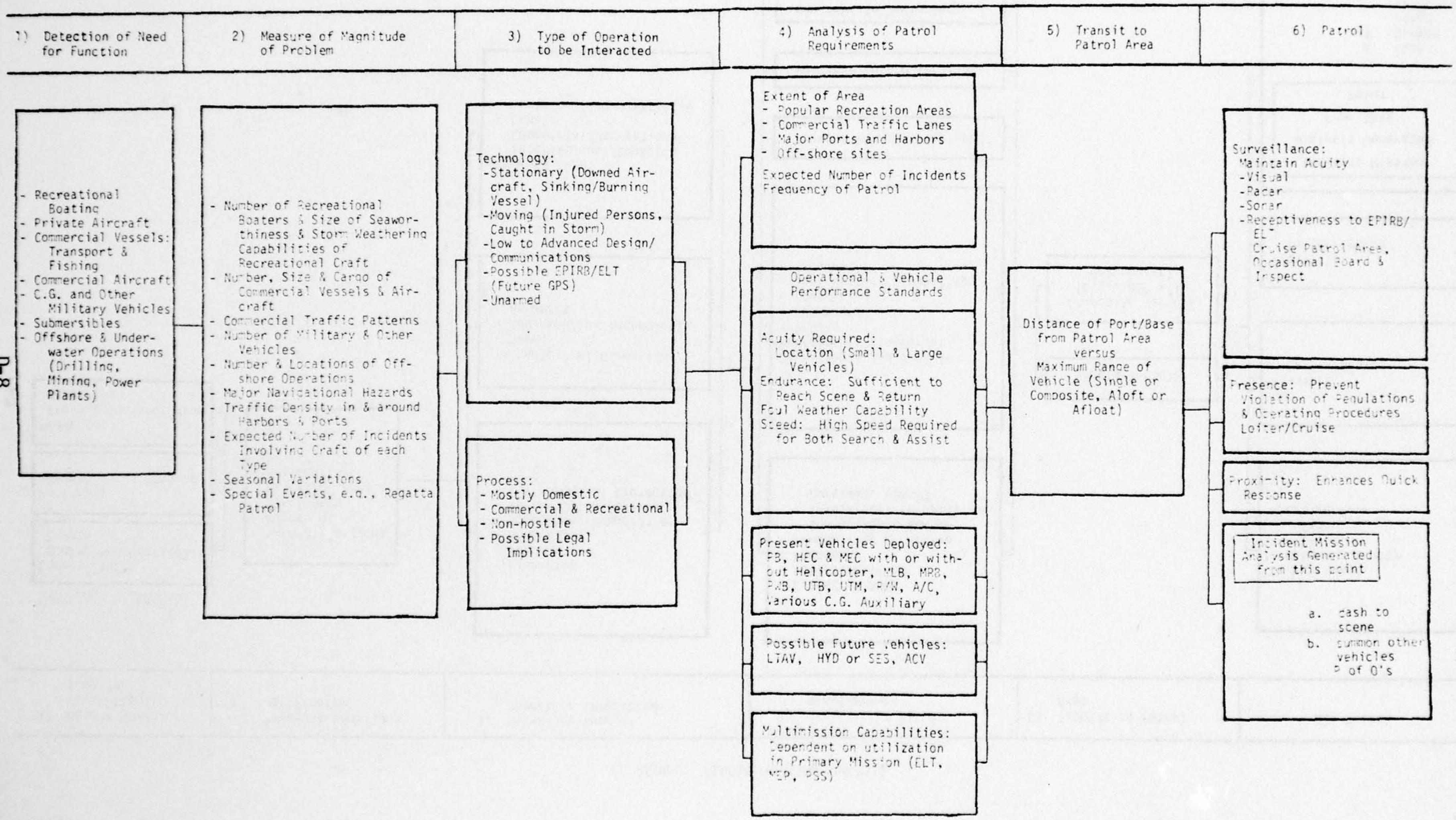


FIGURE D-7

=9 LAW ENFORCEMENT PATROL MISSION FLOW (HIGH SEAS: FISHERIES)

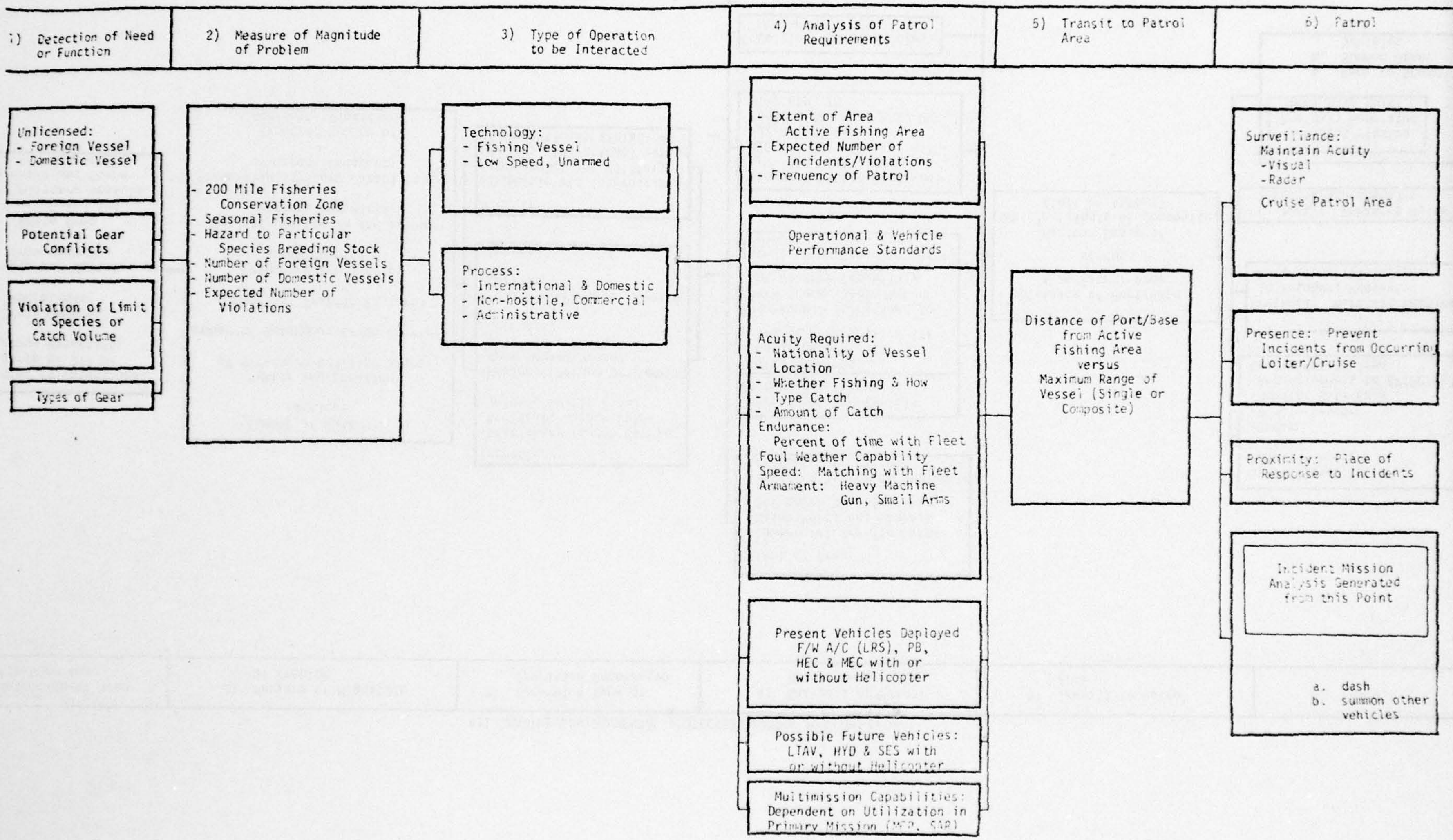


FIGURE D-8

#11 MARINE ENVIRONMENTAL PROTECTION PATROL MISSION FLOW

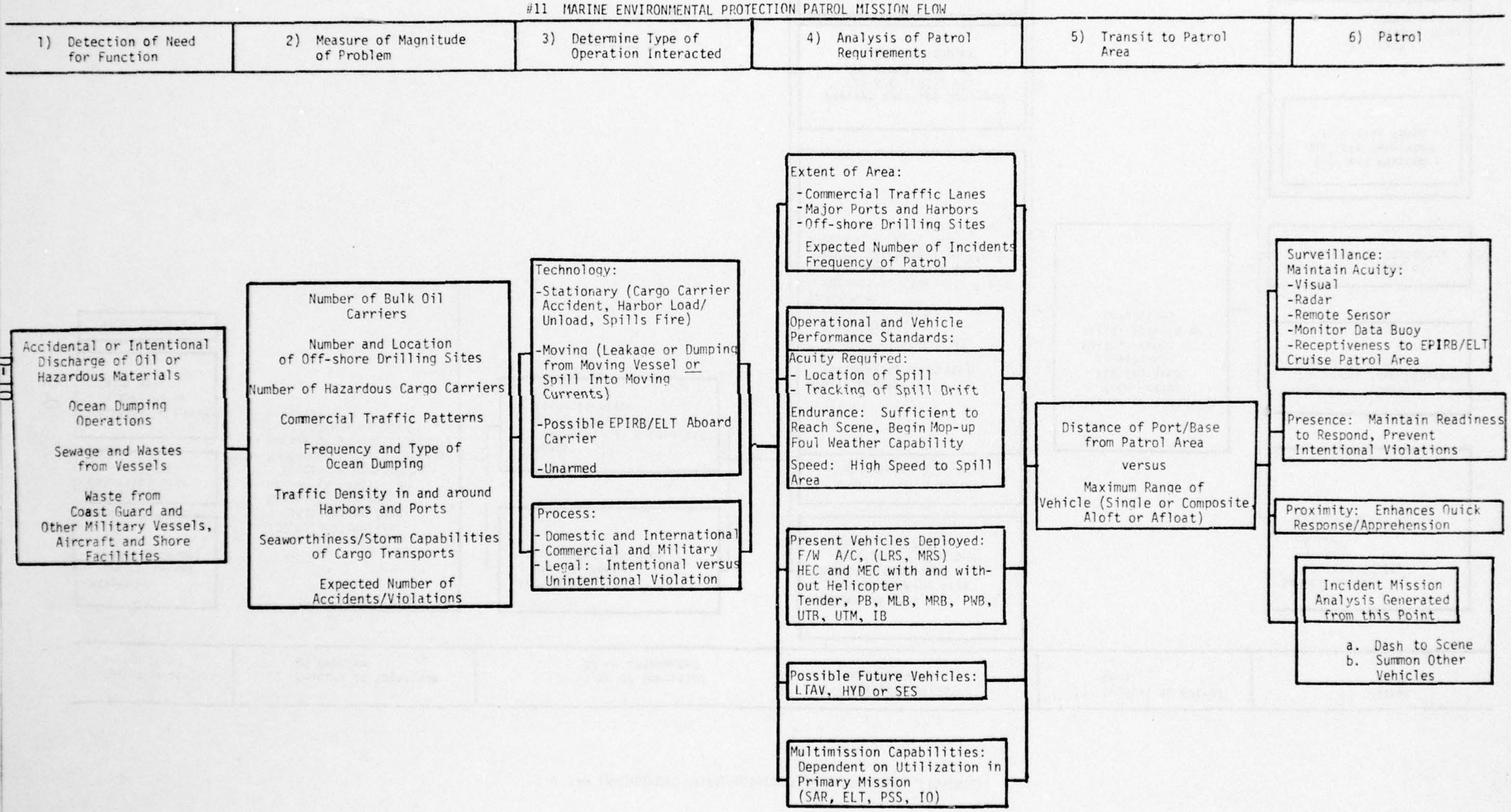


FIGURE D-9

#12 DOMESTIC ICE OPERATIONS PATROL MISSION FLOW

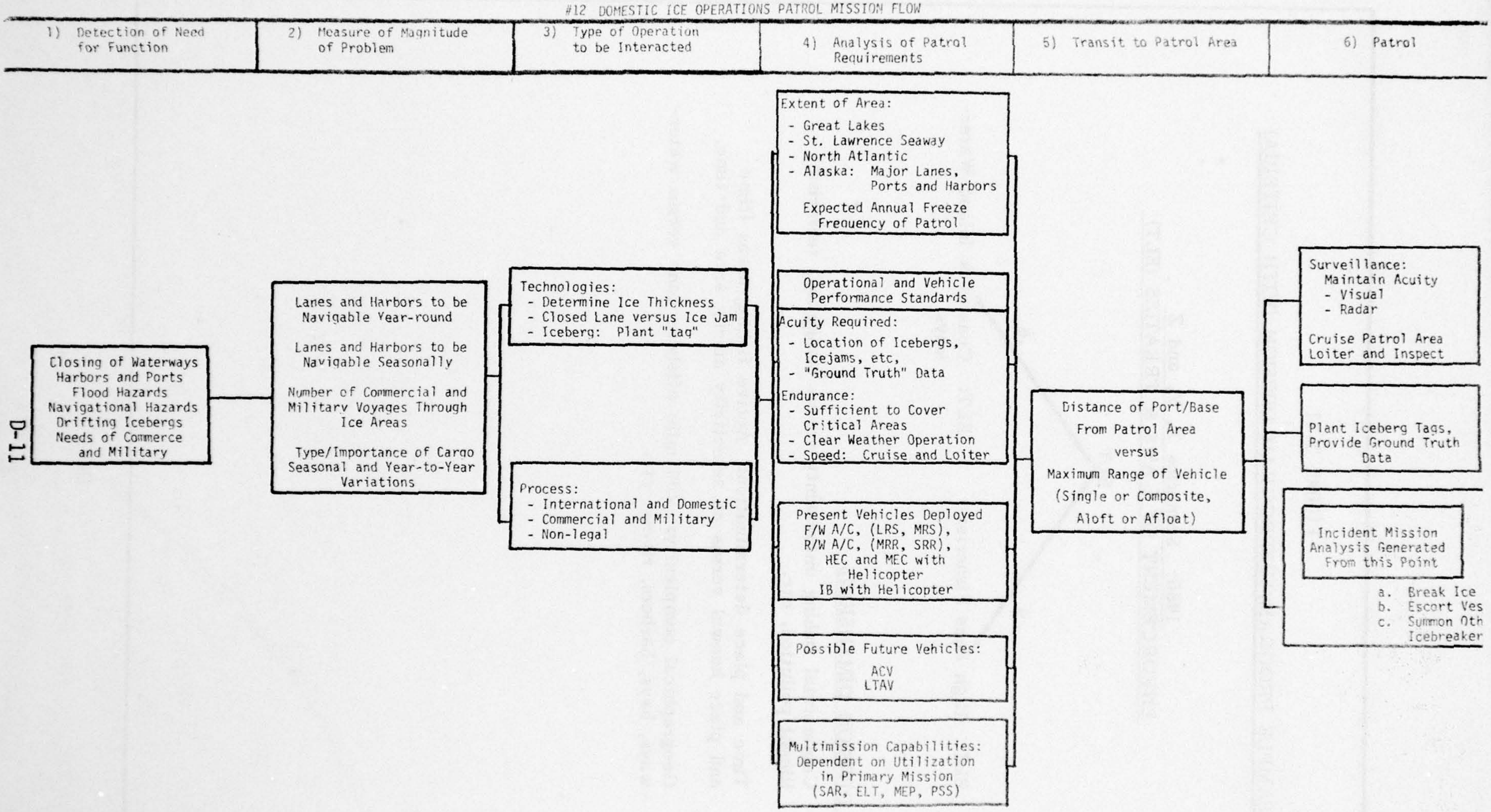
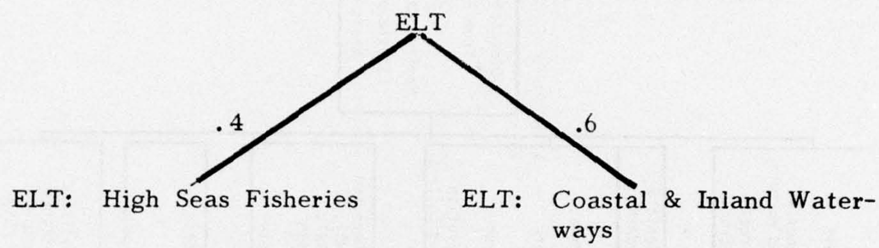


FIGURE D-10

FIGURE D-11

SAMPLE PROGRAM/SUBPROGRAM DIVISION (WITH CRITERIA)

1980: Scenarios X, Y, and Z
ENFORCEMENT OF LAWS & TREATIES (ELT)



ELT DIVISION DIMENSIONS

1. Commercial fishing uncertainty versus smuggling, terrorism, illegal pollution, etc.

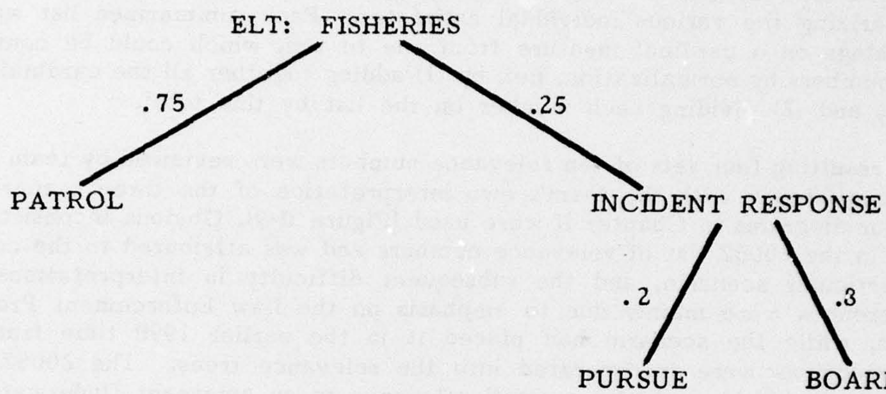
2. Time and place determination: Active fishing areas (time and place known) versus no selectivity among area and time.

3. Geographical complexity: 200 mile offshore zone versus waterways, bays, harbors, rivers, etc.

FIGURE D-12

SAMPLE SUBPROGRAM/ACTIVITY/TASK DIVISION (WITH CRITERIA)

1980: Scenarios X, Y, and Z
ELT: High Seas Fisheries



Patrol: Industrial regulation, enforcement of standards, continuous business participants.

- presence - prevention (RN=.5)
- proximity - on location for incident response (RN=.25)
- surveillance - includes some boarding (RN=.25)

Incident Response: Gives credibility to presence/proximity.

Pursue

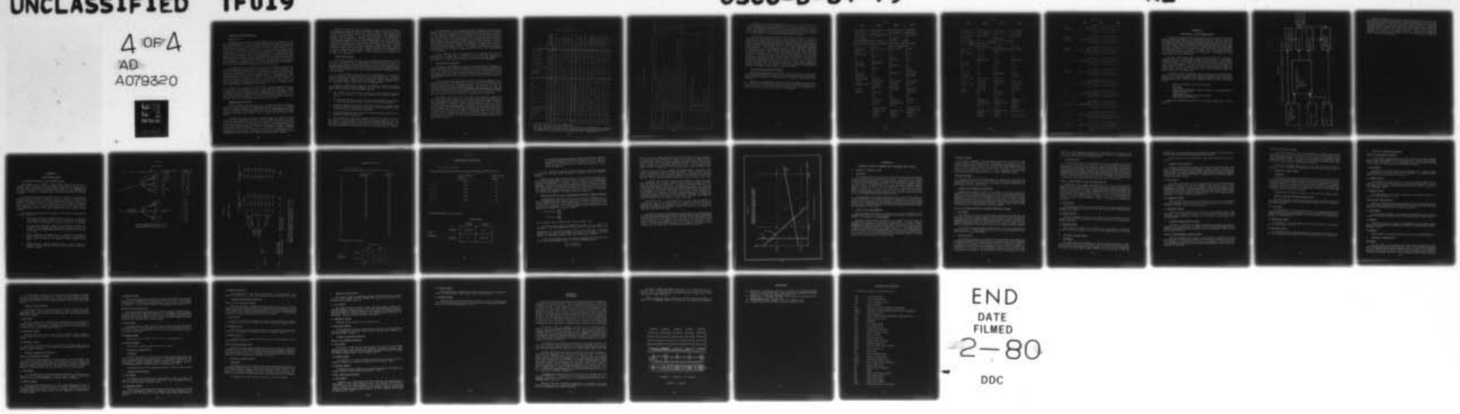
- Commercial vessels only; vessel technology for fishing, not escaping.
- Other enforcement channels available: administrative, bureaucratic.

Board

- Inspect size of catch, species, equipment, etc.
- Seize, arrest.

AD-A079 320 NERO AND ASSOCIATES INC PORTLAND OR F/G 13/10
TECHNOLOGY ASSESSMENT OF LOW ENERGY VEHICLES.(U)
SEP 79 H A LINSTONE, R DAWSON, Y GUR DOT-CG-835030
UNCLASSIFIED TF019 USCG-D-64-79 NL

4 OF 4
AD
A079320



END
DATE
FILMED
2-80
DDC

2. Assignment of Relevance Numbers

Program Level

Information used for relevance number assignment at the topmost level of each tree came primarily from a set of exercises conducted with Coast Guard personnel during the presentation of the project team's Interim Report. During that presentation, the personnel in attendance were asked first to rank the relative importance of the selected operating programs on a scale from one to ten and, second, to read the three scenarios X, Y, and Z, and, in terms of these scenarios, give corresponding rankings of the programs for the year 2005. Thus, each individual in the group produced four separate lists, each ranking the same set of ten programs on one cardinal scale. These rankings were then integrated using an averaging procedure to produce four synthesized lists summarizing the various individual estimates. Each summarized list was also a set of rankings on a cardinal measure from one to ten, which could be converted to relevance numbers by normalization, i.e., by (1) adding together all the cardinal numbers on the list, and (2) dividing each number on the list by this total.

The resulting four sets of ten relevance numbers were reviewed by team members to ensure consistency with the team's own interpretation of the three scenarios. The time contour diagrams in Chapter II were used (Figure II-9). Obvious inconsistency was found only in the 2005Z list of relevance numbers and was attributed to the complexity of that particular scenario, and the subsequent difficulty in interpretations. These small differences were mainly due to emphasis on the Law Enforcement Programs in later years, while the scenario had placed it in the earlier 1990 time frame. The needed corrections were incorporated into the relevance trees. The 2005Z list was also further adjusted by assigning a small relevance to an emergent Underwater Safety and Security Program (USS) consistent with Scenario Z.

This use of the scenarios was preferred over a straight interpolation between 1980 and 2005 values, because of the time contours involved (Figure II-9). Scenario Y emphasized ELT and MO/MP type duties in this period with a subsequent decline by 2005, and Scenario Z emphasizes ELT and MEP type duties in the 1990's. Once again, the procedure applied here was to first develop cardinal measures from one to ten, and then compute relevances. This completes a set of seven lists of relevance numbers needed for the operating program level of all the trees.

Subprograms/Activities/Tasks

Further refining our interpretations of the scenarios using specific criteria to assess the relative importance of subprograms, activities and tasks, we developed relevance weightings for levels intermediate between the operating programs and the vehicles. The specific criteria under each node of the trees were derived by extending the results of the mission flow analysis. The same criteria were then used for all the trees.

A representative example of each set is given in Figures D-11 and D-12. Figure D-11 shows the subprograms breakdown of ELT into High Seas Fisheries ELT and Coastal and Inland Waterways ELT with three dimensions of relevance: one relating to the type of activity to be interacted, one relating to the certainty/uncertainty of incident, and a third pertaining to the geographical complexity of the regions concerned. The particular relevance numbers, .4 and .6 in the diagram, represent a subjective evaluation by project team members that for 1980 the two subprograms are of approximately equal importance. Smuggling and pollution, activities along coasts and waterways receive only slightly more weight than the protection of fisheries.

Figure D-12 extends this analysis through two more levels for ELT: Fisheries. This subprogram divides into patrol versus incident response activities, and incident response divides further into pursuit and boarding operations. The parameters of relevance for patrol reflect the fact that the Coast Guard is here dealing with a primarily commercial operation. The three major functions of any patrol (presence, proximity, and surveillance) are further weighted relative to one another by a methodological procedure to arrive at a clearer understanding of the overall importance of this particular patrol to the ELT function. Parameters of ELT incident response operations are similarly utilized under the headings of "pursue" and "board". We also consider some of the aspects of activity and task performance that begin to describe the kinds of vehicles that would be used. Thus patrol operations can make good use of aircraft; boarding operations require a surface vessel or else the capacity of an aircraft to set down on water; pursuit of a fishing regulation violator normally does not require very high speeds.

Vehicles/Vehicle Teams

At the bottom levels of each tree we are examining approximately 40 activities and tasks for their performance by approximately 35 vehicles and vehicle teams. We use the Activity/Vehicle analysis cards developed for the mission flow analysis, to establish a rank ordered set of "critical factors" for each task. For example, for ELT Fisheries Patrol the critical factors in order of importance are range (distance endurance rather than time endurance), speed, acuity (visual or electronic), and weather or sea state survivability.

As a second stage of this analysis we focused specifically on the vehicles to develop a snapshot of each vehicle in terms of its critical parameters. The critical parameters employed most frequently are size, range, time endurance, speed capability, acuity, and survivability. Other relevant items pertain to special equipment such as an oceanographic research laboratory or an ice strengthened hull.

Using the critical factors of tasks and the snapshots of vehicles, the analysis matches task factors with vehicle capabilities. For each task, we used the following steps to arrive at a list of vehicle relevance numbers.

(a) The complete list of 35 vehicles and teams was examined, and all items not relevant were excluded, i.e., they were assigned a tacit relevance number of zero.

(b) The remaining vehicles and teams were then ranked ordinally, i.e., from best to worst, using the critical factors to task and performance capabilities.

(c) This ordinal ranking was then used in a mathematical procedure to assign cardinal rankings to vehicles on a scale from one to ten. This again employed a review of critical factors and performance capabilities.

(d) The cardinal values were then converted into relevance numbers using the afore described normalization procedure.

We concluded that the relevance analysis for vehicles in the 1980 tree could be used as input for the other trees. For the 1990X tree, we only needed to review the 1980 analysis of vehicle relevances in the context of advanced design vehicles. This amounted to inserting advanced design vehicles into the existing ordinal lists for each task, assigning appropriate cardinal values, and recalculating the relevance numbers.

The interpretation of the technology forecast employed here was that under adequate R&D effort, any of the advanced design vehicles considered could be available by 1990. Thus, it was assumed that all the vehicles in our list would be available in both 1990 and 2005. In addition, it was assumed that the relative relevance of vehicles for a particular task remains invariant over time. For example, if a helicopter is better than a patrol boat for search operation in 1980 then it will also be better in 1990 and 2005. These assumptions justified leaving the 1990X relevances of vehicles to tasks basically unchanged throughout the remaining five relevance trees. The few minor exceptions were cases in which it was reasonable to assume that the nature of the task itself might change with time. For example, if in future years smugglers use hydrofoils, then the relevance of high performance vehicles to Coast Guard pursuit tasks is increased.

A final conclusive stage in development of the relevance trees was the computation of the importance of vehicles to overall Coast Guard operations, as described in the foregoing. The resulting seven lists of relevance values offered some new perspectives on the future use of vehicles to achieve Coast Guard goals.

3. Relevance Tree Calculations

We present a brief explanation of the reasoning underlying the importance or utility ranking for vehicles given the assumptions of the three scenarios in Chapter II. There is one table for each of the relevance trees discussed in Chapter III. Each table has the same basic structure, with variations only as required on the basis of an interpretation of the scenarios. This basic structure will be explained here in terms of the calculation table for the 1990 relevance tree (of which one section is shown in Table D-1).

Across the top of the 1990 relevance table is a complete description of the hierarchical breakdown of the 1990 relevance tree, i.e., overall Coast Guard operations. Items at the next level are the operating programs. Each of these is represented by a column which is headed by the program's acronym, e.g., SAR, ELT, etc. The next level down consists of columns with the appropriate operating program acronyms and a descriptor of the division at that level, e.g., SAR: Patrol and SAR: Incident Response, and so on for all lower levels, culminating in a bottom level of "activity" or "task". (See the description of the basic structure of relevance trees in Chapter III).

The number shown at the top of each colmn is the relevance (or importance) of the item listed in that column to the item which is immediately next higher in the tree. These numbers are determined by an interpretation of the scenarios using the methods described in Chapter III. Complete notes showing all the criteria of relevance we considered have been omitted. There are different criteria for each node at every level of the basic tree, as appropriate for the types of activities involved. The project team developed a brief list of criteria deemed significant in determining the relevance of that node for each node of the 1980 tree to the next higher one. This work on the 1980 tree then provided the template for interpreting the X, Y, and Z scenarios in 1990 and 2005, (i.e., the same criteria were used in the six "future" trees). Chapter III contains, as an example, the set of criteria used for analyzing the relevance of certain ELT activities.

TABLE D-1

SECTION OF RELEVANCE MATRIX CALCULATION

1990X	Overall Coast Guard Operations	SAR	SAR:Patrol	SAR:Incident	SAR:Incident: Search	SAR:Incident: Rescue	ELT	ELT-Fisheries	ELT -Fisneries: Patrol	ELT -Fisheries: Incident	ELT-Fisheries: Incident Pursue	ELT- Fisheries: Incident Board	ELT-Coastal & Inland	ELT Coastal & Inland:-Patrol	ELT Coastal & Inland: Incident	* ....
		.14	.05	.95	.2	.8	.14	.3	.7	.3	.1	.9	.7	.5	.5	
FW/AC (LRS,MRS)	.038	.07		.07	.09	.06	.07	.08	.11	.01	.09		.07	.10	.04	
FW/AC (CESSNA)	.058	.05	.05	.05	.06	.05	.07	.08	.10	.06	.09	.06	.07	.08	.06	
FW/AC (MRR,SRR)	.055	.07	.05	.07	.06	.07	.05	.02		.06		.07	.06	.04	.07	
FW/AC (SKYCRANE)	.019	.06		.06		.07										
CUTTER WITH HELICOPTER	.036	.08	.09	.08	.07	.08	.09	.10	.09	.11	.11	.11	.09	.08	.09	
CUTTER WITHOUT HELICOPTER	.031	.04	.08	.04	.04	.04	.08	.09	.08	.12	.08	.12	.07	.07	.07	
PB	.034	.04	.08	.04	.04	.04	.06	.09	.07	.12	.07	.13	.05	.07	[illegible]	
*																
LTAV	.044	.06	.05	.06	.08	.06	.07	.07	.10	.01	.10		.07	.09	.04	
WIGE	.011	.06	.03	.06	.05	.06	01	.01	.01	.00	.02		.01	.01	.03	
SEA LOITER	.037	.07	.05	.07	.10	.06	09	.10	.12	.06	.12	.05	.08	.10	.05	
ACV-I	.021	02	.03	.02	.02	.02	04	.01		.07		.08	.05	.04	.06	
ACV-II	.027	04	06	.04	.05	.04	05	.04	.05	.01	.05		.06	.06	.06	
SES	.022	.04	.06	.04	.05	.04	.05	.06	.05	.08	.07	.08	.05	.03	.06	
HYD	.027	.04	.07	.04	.05	.04	.08	.09	.09	.09	.09	.09	.07	.07	.06	
SWATH WITH HELICOPTER	.040	.08	.10	.08	.07	.08	.09	.10	.09	.11	.11	.11	.09	.08	.09	
PLANING CRAFT	.021	.05	.03	.05	.05	.05	.04	.06	.04	.09		.10	.03	.01	.07	
DUMMY **	.213															
TOTAL	1.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	

* A portion of the table has been deleted here.

** This is to allow for activities involving no vehicles (e.g. administrative). Assigning the "dummy vehicle" a relevance of 1.0 for each such activity provided a mathematical cross check of calculations by ensuring that every table column sums to 1.

TABLE D-2

1980 : SCENARIOS X,Y&Z

ELT : COASTAL AND INLAND WATERWAYS

PATROL

Vehicles	Performance Capabilities	Relevance	
FW/AC	L Range, VS-S Time, VH Acuity, H Survivability, H-VH Speed	9	.19
FW/AC (Cessna)	M Range, VS Time, H Acuity, M Survivability, H Speed	8	.17
Cutter with Helicopter	L-VL Range, L-VL Time, M Acuity, H Survivability, S-MS/M-H Speed, ML-L Size	7	.15
PB	M-L Range, M Time, M Acuity, M-H Survivability, MS Speed, M Size	6	.13
Cutter without Helicopter	L-VL Range, L-VL Time, M Acuity, H Survivability, S-MS Speed, ML-L Size	6	.13
RW/AC	S Range, VS Time, H Acuity, M Survivability, M-H Speed	4	.09
PWB	S Range, VS Time, M Acuity, L Survivability, MS Speed, S Size	4	.09
Submarine II	M Range, Time, L Acuity (good for clandestine surveillance), H Survivability, S-MS MS-M Speed, M-ML Size	2	.03
Submarine I	S Range, S Time, L Acuity (good for clandestine surveillance), H Survivability, MS-M Speed, L Size	1	.02

L=Long or Low, V=Very, S= Short or Slow, H= High M=Medium, etc.

Ranking of Performance Capabilities

1. Range or Time Endurance -transit and/or loiter
2. Acuity
3. Survivability
4. Speed
5. Appropriate Size - medium

Coastal - mostly open waters

Inland - mostly constricted waters; problem exists with maneuverability of large vessels.

Down the side of Table D-1, marking the rows, is a list of acronyms designating the vehicles and/or vehicle teams. In particular, the 1980 tree contains only currently existing vehicles; for the 1990 and 2005 trees, the list includes vehicles with advanced design. In Chapter IV, we noted that all potential future fleet vehicles considered can be made available by 1990, so all such advanced design vehicles are relevant in both 1990 and 2005, i.e., have relevance numbers larger than zero.

The relevance of each vehicle type to each bottom level "acuity" or "task" was determined by listing "snapshots" of each vehicle type in terms of performance capabilities and matching those capabilities with the requirements of the "activity" or "tasks". Table D-2 gives an example of how the snapshots were used to provide specific relevance numbers for vehicles with respect to an ELT Coastal and Inland Waterways Patrol Operation. At the bottom is a list of the vehicle performance capabilities deemed important to this particular patrol operation. These performance capabilities are ranked from most to least important; and this ranking is then used to rank order the vehicles from best to worst. Vehicles and/or teams not shown in Table D-2 were examined in a preliminary review of the entire vehicle/team list and were determined to have no (i.e., zero) relevance to this particular patrol operation. In the manner described in Chapter III, the rank ordering was then converted to a cardinal ranking by assessing the importance/utility of each vehicle on a scale of 1 to 10 (the best vehicles being ranked high and the worst ranked low). These cardinal rankings are shown in the column which is second from the right in the table. The cardinal values were then normalized to add up to one (1). These normalized values are the relevance numbers. They appear in the far right column of the table.

4. Vehicle Relevance/Importance Rankings

The first two tables below (D-3, D-4) are complete versions of the partial lists given in Figure III-8 and III-9 of Chapter III. They show the final results of the vehicle relevance analysis regarding the relative importance of vehicles to overall Coast Guard operations.

Table D-5 is a larger version of the partial list given in Figure III-10 of Chapter III. It shows the same information as above, but in a format which focuses on one vehicle at a time. For each of the primary vehicles we show the ranking that the vehicle holds in each of the seven scenario-year combinations.

TABLE D-3

1980	1990X	1990Y	1990Z
RW/AC (MRR,SRR)	RW/AC (MRR,SRR)	RW/AC (MRR,SRR)	RW/AC (MRR,SRR)
CUTTER (HEC,MEC)	FW/AC (CESSNA)	CUTTER (HEC,MEC)	CUTTER (HEC,MEC)
FW/AC (CESSNA)	CUTTER (HEC,MEC)	*LTAV*	FW/AC (CESSNA)
FW/AC (LRS,MRS)	*LTAV*	FW/AC (CESSNA)	PB
PB	FW/AC (LRS,MRS)	*SEA LOITER*	*LTAV*
PWB	PWB	FW/AC (LRS,MRS)	FW/AC (LRS,MRS)
IB	*SEA LOITER*	PWB	PWB
SEAGOING TENDER	PB	PB	*SEA LOITER*
HARBOR TUG	IB	*ACV II*	IB
RW/AC (SKY CRANE)	*SWATH SHIP*	*HYD*	*ACV II*
UT	*HYD*	*SWATH SHIP*	*HYD*
MLB	*ACV II*	HARBOR TUG	*SWATH SHIP*
RIVER TENDER	SEAGOING TENDER	*SES*	UT
COASTAL TENDER	UT	*PLANING CRAFT*	*ACV I*
MRB	HARBOR TUG	THPB	THPB
THPB	*SES*	IB	HARBOR TUG
INLAND TENDER	THPB	SEAGOING TENDER	SEAGOING TENDER
OCEANGOING TUG	*ACV I*	UT	*PLANING CRAFT*
CONSTRUCTION TENDER	*PLANING CRAFT*	*ACV I*	*SES*
ANB, TANB	RW/AC (SKY CRANE)	RW/AC (SKY CRANE)	RW/AC (SKY CRANE)
OCEANOGRAPHIC CUTTER	RIVER TENDER	RIVER TENDER	RIVER TENDER
BU	INLAND TENDER	COASTAL TENDER	MLB
SUBMARINE I	MLB	INLAND TENDER	COASTAL TENDER
SUBMARINE II	COASTAL TENDER	MLB	INLAND TENDER
	MRB	MRB	MRB
	WIGE	*WIGE*	*WIGE*
	OCEANGOING TUG	OCEANGOING TUG	OCEANGOING TUG
	ANB, TANB	CONSTRUCTION TENDER	ANB, TANB
	BU	ANB, TANB	BU
	CONSTRUCTION TENDER	BU	CONSTRUCTION TENDER
	OCEANOGRAPHIC CUTTER	OCEANOGRAPHIC CUTTER	OCEANOGRAPHIC CUTTER
	SUBMARINE I	SUBMARINE I	SUBMARINE I
	SUBMARINE II	SUBMARINE II	SUBMARINE II

TABLE D-4

1980	2000X	2000Y	2000Z
RW/AC (MRR,SRR)	RW/AC (MRR,SRR)	RW/AC (MRR,SRR)	RW/AC (MRR,SRR)
CUTTER (HEC,MEC)	CUTTER (HEC,MEC)	CUTTER (HEC,MEC)	CUTTER (HEC,MEC)
FW/AC (CESSNA)	FW/AC (CESSNA)	*LTAV*	FW/AC (CESSNA)
FW/AC (LRS,MRS)	*LTAV*	FW/AC (CESSNA)	*LTAV*
PB	PB	PWB	PWB
PWB	PWB	PB	PB
IB	FW/AC (LRS,MRS)	*SEA LOITER*	*SEA LOITER*
SEAGOING TENDER	*SEA LOITER*	FW/AC (LRS,MRS)	FW/AC (LRS,MRS)
HARBOR TUG	IB	HARBOR TUG	UT
RW/AC (SKY CRANE)	*SWATH SHIP*	UT	IB
UT	HARBOR TUG	IB	*ACV I*
MLB	SEAGOING TENDER	THPB	SEAGOING TENDER
RIVER TENDER	*ACV II*	*SWATH SHIP*	THPB
COASTAL TENDER	*HYD*	*ACV II*	*SWATH SHIP*
MRB	UT	*ACV I*	*ACV II*
THPB	*SES*	*HYD*	*HYD*
INLAND TENDER	THPB	SEAGOING TENDER	HARBOR TUG
OCEANGOING TUG	*ACV I*	*SES*	*PLANING CRAFT*
CONSTRUCTION TENDER	RW/AC (SKY CRANE)	*PLANING CRAFT*	*SES*
ANB, TANB	*PLANING CRAFT*	RW/AC (SKY CRANE)	RW/AC (SKY CRANE)
OCEANOGRAPHIC CUTTER	RIVER TENDER	RIVER TENDER	COASTAL TENDER
BU	COASTAL TENDER	MLB	RIVER TENDER
SUBMARINE I	INLAND TENDER	MRB	INLAND TENDER
SUBMARINE II	MLB	COASTAL TENDER	MLB
	MRB	INLAND TENDER	MRB
	WIGE	*WIGE*	*WIGE*
	OCEANGOING TUG	OCEANGOING TUG	OCEANGOING TUG
	CONSTRUCTION TENDER	CONSTRUCTION TENDER	SUBMARINE I
	ANB, TANB	ANB, TANB	SUBMARINE II
	BU	BU	ANB, TANB
	OCEANOGRAPHIC CUTTER	OCEANOGRAPHIC CUTTER	CONSTRUCTION TENDER
	SUBMARINE I	SUBMARINE I	BU
	SUBMARINE II	SUBMARINE II	OCEANOGRAPHIC CUTTER

TABLE D-5

	1980		1990	2000
RW/AC (MRR, SRR)	1	X	1	1
		Y	1	1
		Z	1	1
CUTTER (HEC,MEC)	2	X	3	2
		Y	2	2
		Z	2	2
FW/AC (Cessna)	3	X	2	3
		Y	4	4
		Z	3	3
LTAV	Advanced	X	4	4
		Y	3	3
		Z	5	4
FW/AC (LRS,MRS)	4	X	5	7
		Y	6	8
		Z	6	8
PB	5	X	8	5
		Y	8	6
		Z	4	6
PWB	6	X	6	6
		Y	7	5
		Z	7	5
Sea Loiter	Advanced	X	7	8
		Y	5	7
		Z	8	7
IB	7	X	9	9
		Y	16	11
		Z	9	10
SWATH SHIP	Advanced		10	10
			11	13
			12	14

APPENDIX E

The Concept of a Total Energy System

The term Total Energy System (TES) usually refers to systems which efficiently utilize all stages and outputs of an energy production system. Attention to date has been limited to systems which produce electricity on-site and utilize the waste heat resulting from electric power generators for purposes such as space heating and cooling, and water heating. Further, conventional power generation systems (i.e., those using fossil fuels to produce electricity) can be used in tandem with non-conventional systems (i.e., solar and solid waste), by restricting the use of the former to peak-load hours and when solar energy is not available. In addition, the use of energy technologies, such as fuel cells which produce water as a by-product, can supply part of the requirements for water on-board ships.

One type of total energy system concept is shown in Figure E-1. This TES is centered around on-site electric power generation for which there are several options: including gas turbines, diesel engines, fuel cells, solar photovoltaics. The electricity is used for meeting the power needs of vehicle and non-vehicle technologies as well as for heating and lighting. The waste heat recovery unit collects and adjusts the quality of heat so that it is suitable for uses such as space heating and cooling, and water heating. The waste heat is utilized in tandem with solar energy to obtain the optimal efficiency of the total system.

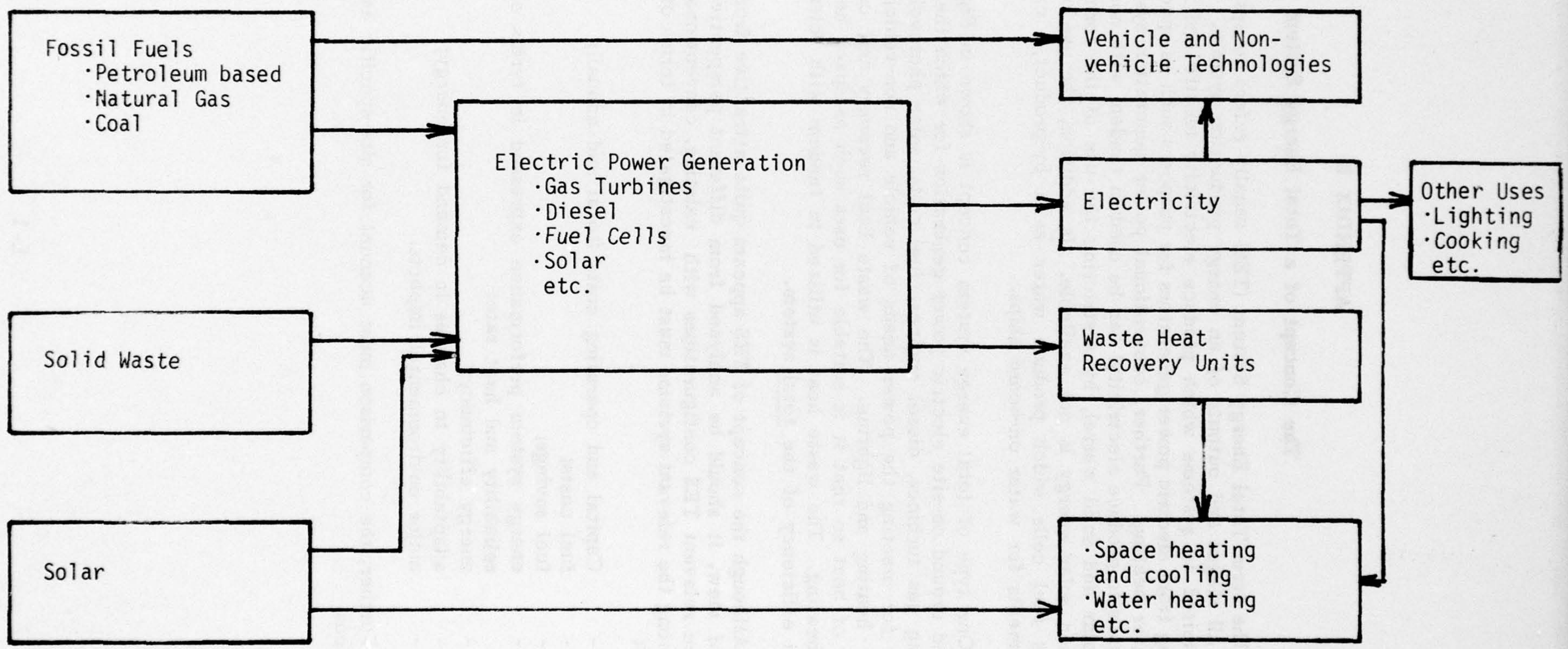
Although the concept of TES appears quite attractive from an energy efficiency point of view, it should be analyzed from different perspectives. The analysis must compare relevant TES configurations with existing, conventional systems. The trade-offs among the relevant systems must be investigated in terms of at least the following factors:

- Capital and operating costs (total and annual);
- fuel costs;
- fuel savings;
- energy system performance expressed in terms of parameters such as reliability and heat rate;
- energy efficiency;
- adaptability to changes in demand for energy;
- major environmental impacts.

Further, the comparison must account for site-specific aspects, such as weather conditions.

FIGURE E-1

SIMPLIFIED REPRESENTATION OF ONE TYPE OF TOTAL ENERGY SYSTEM CONCEPT



The TES concept is not a new one, although its applications in the U.S. have been limited. In European countries (e.g., Sweden) systems based on the TES concept have been widely used for some time. We could not fully investigate the TES concept in this study because it would have required collecting detailed data on energy use and supply patterns in major Coast Guard vehicles and on-shore facilities. Such data collection efforts were beyond the scope of this study. However, on the basis of our knowledge of the nature of the energy needs of the Coast Guard, a preliminary investigation to determine the application of TES for appropriate Coast Guard use appears warranted and worthwhile.

APPENDIX F

Level-3 Energy Analysis

1. An Alternative Approach to Level-3 Energy Analysis

The approach used for Level-3 analysis involves parametric optimization to determine the least energy intensive and quickest response time alternative (vehicle mix and tactics). One limitation of that approach is that it does not explicitly show the range of trade-offs between performance parameter(s) (e.g., speed, response time) and energy consumption, as dependent upon actual (numerical values of) distances involved.

An example of an alternative approach based on a simulation, decision type of framework is described here. We consider a scenario involving a search and rescue mission taking place in 1980 and 2000, using different vehicle mixes to respond to the situation. The distance between the patrol vehicle and the incident, the distance between the incident and the Coast Guard base, and speed are the major variables which determine the energy consumption and response time. The best vehicle mix can then be determined in terms of the range of values which can be assigned to these variables.

The approach, graphically depicted in Figures F-1 and F-2 for the 1980 and 2000 situations, consists of:

a. Determining the number of stages or branches of the tree. In this case, three stages are assumed: search, rescue, and escorting the distressed vehicle to the Coast Guard base. Any number of stages can be considered.

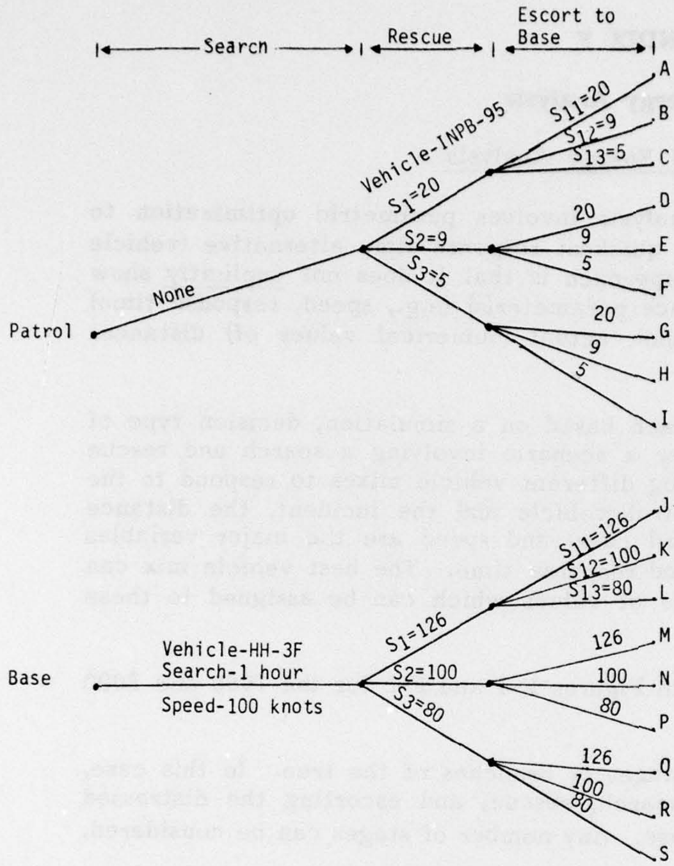
b. For each stage, alternative tactics are determined by specifying the vehicle to be used in each stage and the speed at which the vehicle will operate. Any other performance parameter can be substituted for speed, if so desired.

c. Energy consumption and response time are computed for each stage (or branch of the tree), as well as on their total values, by summing the values over all the branches. The totals are shown in Figures F-1 and F-2.

d. Possible (feasible) mutually exclusive options are then selected to determine the best 1980 and 2000 options in this case, as depicted in Tables F-1 and F-2.

FIGURE F-1

SCENARIO IN 1980

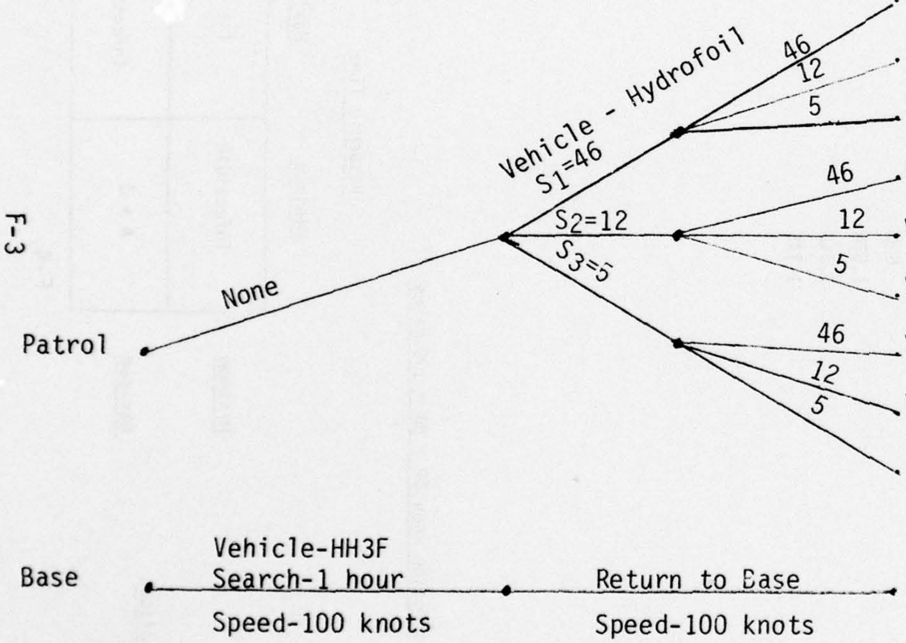


	Total Energy Consumption (Gallons)	Total Response Time (hours)
A	6.25 (DP+DB)	.05DP + .05DB
B	6.25 (DP+DB)	.05DP + .11DB
C	6.25 (DP+DB)	.05DP + .2DB
D	DP+ 6.25 DB	.11DP + .05DB
E	DP+DB	.11DP + .11DB
F	DP+DB	.11DP + .2DB
G	DP+ 6.25 DB	.2DP + .05DB
H	DP+DB	.2DP + .11DB
I	DP+DB	.2DP + .2DB
J	120 + 3DB for each path	1 + .016DB
K		1 + .018DB
L		1 + .021DB
M		1 + .018DB
N		1 + .020DB
P		1 + .023DB
Q		1 + .021DB
R		1 + .023DB
S		1 + .026DB

DP= Distance between patrol vehicle and incident
DB= Distance between incident and base
Numbers on branches are speed options, in knots

FIGURE F-2

SCENARIO IN 2000



	Total Energy Consumption (gallons)	Total Response Time (hours)
I	13.2 (DP+DB)	.02DP + .02DB
II	13.2DP + 3.8DB	.02DP + .08DB
III	13.2DP + 3.6DB	.02DP + .2DB
IV	3.8DP + 13.2DB	.08DP + .02DB
V	3.8DP + 3.8DB	.08DP + .08DB
VI	3.8DP + 3.6DB	.08DP + .2DB
VII	3.6DP + 13.2DB	.2DP + .02DB
VIII	3.6DP + 3.8DB	.2DP + .08DB
IX	3.6DP + 3.6DB	.2DP + .2DB
X	120 + 1.5DB	1 + .01DB

DP= Distance between patrol vehicle and incident
DB= Distance between incident and base
Numbers on branches are speed options, in knots

TABLE F-1

DETERMINING BEST 1980 OPTIONS

Let DP = DB = 100 miles

A. Possible, mutually exclusive options for Search and Rescue (Figure -1) are:

	Energy Consumption (Gallons)	Response Time (Hours)
A+J	1,670	12.6
B+J	1,145	18.6
C+J	1,145	27.6
E+J	620	24.6
F+J	620	33.6
I+J	620	42.6
A+K	1,670	12.8
B+K	1,145	18.8
C+K	1,145	27.8
E+K	620	24.8
F+K	620	33.8
I+K	620	42.8
A+L	1,670	13.1
B+L	1,145	19.1
C+L	1,145	28.1
E+L	620	25.1
F+L	620	34.1
I+L	620	43.1
A+P	1,670	13.0
B+P	1,145	19.0
C+P	1,145	28.0
E+P		25.0
F+P		34.0
I+P		43.0
A+S		13.6
B+S		19.6
C+S		28.6
E+S		25.6
F+S		34.6
J+S		43.6

B. Best Option when DP = DB = 100 miles

Energy Consumption	Response Time: Minimum	Response Time: Maximum
Minimum	Infeasible	I + J
Maximum	A + J	Infeasible

TABLE F-2

DETERMINING BEST 2000 OPTIONS

Let DP = DB = 100 miles

A. Possible, mutually exclusive options for Search and Rescue (Figure F-2) are:

	Energy Consumption (Gallons)	Response Time (Hours)
I + X	3,910	6
II + X	1,970	12
III + X	1,950	24
V + X	1,030	12
VI + X	1,010	18
IX + X	990	30

B. Best Option when DP = DB = 100 miles

Energy Consumption	Response Time: Minimum	Response Time: Maximum
Minimum	Infeasible	IX + X
Maximum	I + X	Infeasible

e. From step 4, the best option among the 1980 and 2000 options is identified by comparing information in Section B of Tables F-1 and F-2. Thus, we find that the best option from an energy perspective is I+J: WPB and HH-3F, and the best options from a response time perspective is I+X: HH-3F and Hydrofoil.

It can be noted that the approach explicitly indicates the benefits and penalties associated with operating vehicle alternatives, at different speeds over different distances.

Compared to the approach used in section V - D, the alternative approach could be more time consuming since it involves a step-wise search for the best alternative. However, when programmed on a computer, it can be efficiently executed, using simple algorithms. It should also be noted that the approach can easily be modified to consider probabilistic aspects by ascribing appropriate probability values on each branch of the tree. The probability would indicate the likelihood that the vehicle will be operated at a specific value of speed, in this case; but any other parameter can be so specified - for example, the probability of locating a target in a given time.

2. Mathematical Model for Level-3 Analysis (Energy Analysis of Aggregate Missions)

The problem addressed by the model is: Given a set of n alternatives Ai, i=1, 2, ...n for performing a given mission, determine the alternatives with best (lowest) energy consumption and best (lowest) response time. The model is supplied with data on vehicle mix, tactics to be used, energy consumption, and speed profile of each vehicle used in the mission. The model determines the least energy intensive and quickest way to perform the mission, as follows:

$$\text{Let } RE\ (Ai,\ Aj) = \frac{E(Ai)}{E(Aj)}$$

$$RT\ (Ai,\ Aj) = \frac{T(Ai)}{T(Aj)}$$

where E denotes energy consumption and T denotes response time.

The model makes a pairwise comparison (i.e., taken two at a time) of the alternatives. For n alternatives, there are $\binom{n}{2}$ pairwise energy and response time comparisons. For the incident missions, RE and RT are functions of normalized distances between vehicle Vi and incident, and vehicle Vj and incident. For patrol missions, the independent variable is the area to be searched or patrolled.

In the energy analysis, and for the missions requiring incident response, there were at most two normalized distances. For the two-dimensional case:

$$RE = f1\ (R1,\ R2)$$
$$RT = f2\ (R1,\ R2)$$

Here R1 and R2 are normalized distances; RE and RT are ratios of energy consumption and response time for the alternatives in question. For example, R1 = distance between the base and the incident; R2 = distance between the position of the vehicle on patrol and the incident. For each pairwise comparison, the R1 - R2 space is divided into regions of preference by specifying bounds for R1 and R2. The boundary of these regions is always a straight line. For the $\binom{n}{2}$ pairwise energy (or response time) comparisons, the R1-R2 space is divided into multiple regions of preference. The ranking of alternatives is carried out for each region. Further, since we bound the values of R1 and R2 in terms of feasible limits, we are interested only in ranking, and the alternatives within the regions of preference as bounded by the values of R1 and R2. The R1, R2 bounds are specified by the user as inputs to the model.

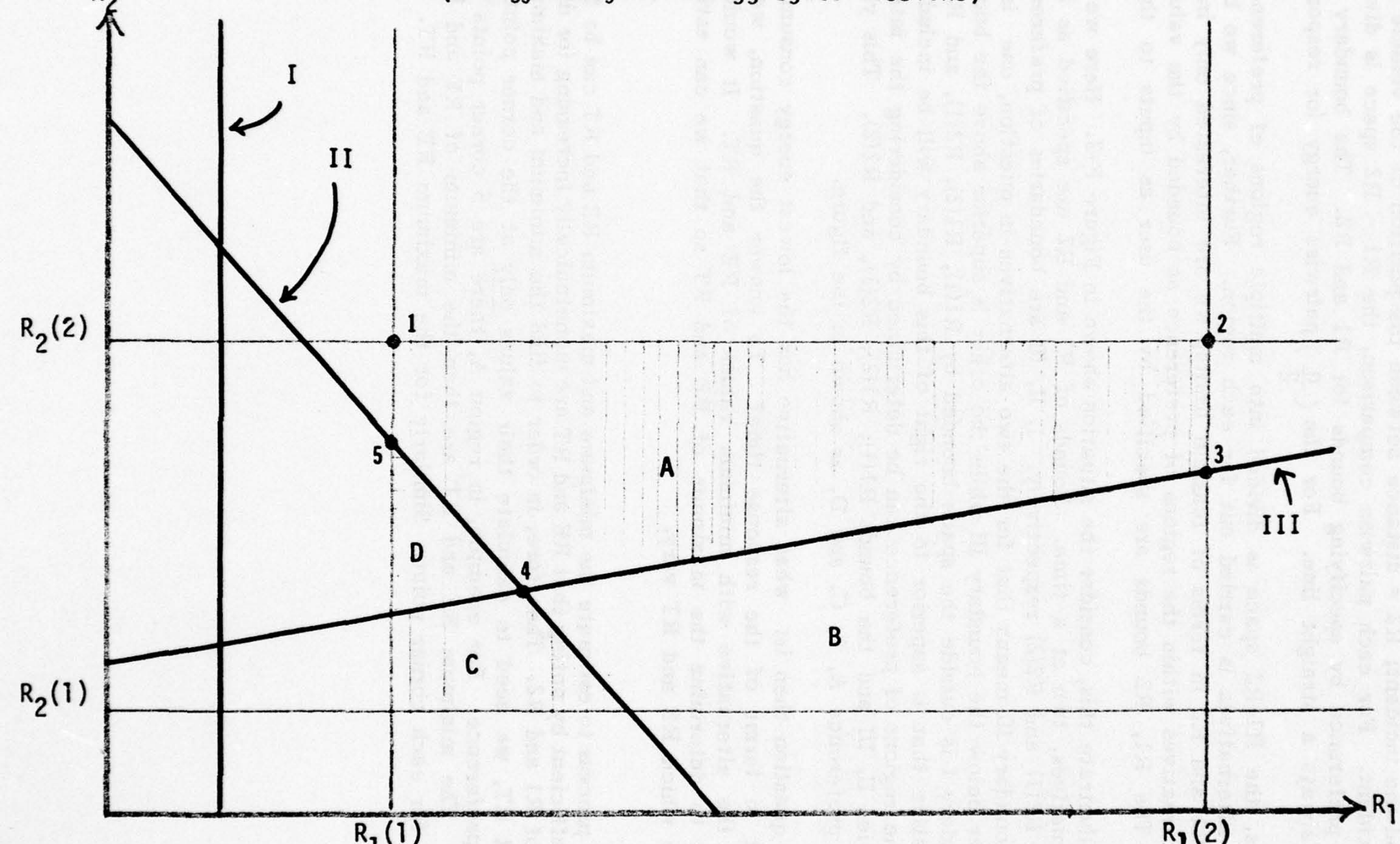
To illustrate this, consider the situation shown in Figure F-3. Here we compare three alternatives, two at a time. Bounds of R1 and R2 are specified as R1(1) and R1(2), and R2(1) and R2(2) respectively. I, II, III are boundaries of preference. For example, boundary III means that for the two alternatives in question, one is superior to the other below the boundary III while the other is superior above the boundary III. Since Boundary I is outside the space bounded by R1(1), R1(2), R2(1), and R2(2), only the alternative that is superior to the right of this boundary will be included in the ranking. The regions of preference can be determined by considering the intersections of boundaries II, III and the bounds R1(1), R1(2), R2(1), and R2(2). This yields four regions of preference A, B, C. and D, as shown in the figure.

The question then is: what alternative has the lowest energy consumption and is quickest in terms of the response time? To answer the question, we need to determine the alternative with minimum values of RE and RT. It would also be interesting to determine the maximum of RE and RT so that we can estimate the range over which RE and RT vary.

The process to estimate the minimum and maximum RE and RT can be facilitated and made efficient by noting that RE and RT are monotonically increasing (or decreasing) functions of R1 and R2. Therefore, in order to find the minimum and maximum values of RE and RT, we need to calculate their values only at the corner points of each region of preference. For example, in region A, there are 5 corner points - 1, 2, 3, 4, and 5. The minimum RE and RT are then the minimum of RE and RT values calculated for each corner point. Similarly for the maximum RE and RT.

FIGURE F-3

MATHEMATICAL MODELS FOR LEVEL 3 ANALYSIS
(Energy Analysis of Aggregate Missions)



For explanation see Page F-7

APPENDIX G

Rationale for Values of Variables used in Generalized SOPA Analysis

1. Situation 1 - Scenario X, 1990

a. Description:

The essential points of the X scenario for 1990 involves growing resource shortages, forcing initial shifts toward alternative energy sources. The long lead times involved in these changes however lead to a situation of general economic decline. Socially, this leads to a general lowering of the quality of life. Education, for example, reaches its lowest levels - and unemployment grows as the government institutes austerity programs. Research is pushed in the area of substitutes for raw materials. Military budgets remain high, but the U. S. is not involved in war. Specifically, Coast Guard mission weightings tend to emphasize the role of ELT and MEP. Growing shortages tend to increase smuggling and other criminal activity. The push toward new resources leads to the introduction of prototype undersea vessels.

Technologically, by 1990, the operational fleet mix of the Coast Guard could include MRS aircraft, 270-foot WMEC cutters, SRR helicopters, Air Cushion Vehicles, electric cars and various non-vehicle technologies - specifically MTCS, remote sensors (IR, SAR, etc.), completed Loran C and Omega systems and an operational GPS system. New fuel sources potentially available by 1990 incude synthetic fuels from oil shale and widespread use of fuel cells.

b. Analysis of the Task Requisites:

The Task under study here is the increased Coast Guard responsibility for ELT and MEP missions under the conditions specified in the descriptive materials. The first variable to be examined is the Size Variable.

Utilizing the scales reported in Reference 2 of Chapter II we can classify the increased Coast Guard task as reflecting a coded value 6. The shift in mission weightings from a primacy of SAR, and a relatively low rating of MEP in 1980 to making ELT and MEP most important in 1990 follows the shift of the descriptor values in changing the assigned value for this variable from 4 to 6. The change represents a situation where the task requires the addition of more units, each of which perform different activities. ELT units will probably require armed vessels, whereas MEP units do not need the same sort of sophisticated search and location devices and boarding capacity that would be involved in an ELT mission.

Adaptability Variable

The mission weightings of the Coast Guard shift in this scenario, but no major changes are made in the characteristics of the programs that are involved; i.e., ELT activities increase, but the nature of ELT - the prevention of smuggling, crimes, etc. does not change in any major fashion in this situation. Some MEP changes may indeed be involved as the seabed is utilized in the search for new resources - but the essential parameters of the MEP program remain intact. These considerations lead us to shift the coded values for this variable from 4 to 5 for the Adaptability Variable.

Space/Time Variable

The operations of the Coast Guard remain at a coded value of 6, since in the 1990 situation as well as that of 1980 inputs come from several places, and are transported in their use. Task routines, e.g., missions, are partially scheduled (in the patrol mode), but not at fixed intervals.

c. Analysis of the Organizational Responses:

Organizational responses will be of two varieties. In the first case (A), we assume that the Coast Guard has available to it all of the new and improved technologies that are potentially scheduled for development by 1990 in the Technological Forecast (Chapter IV). In case B, we shall consider the Coast Guard as having a vehicle capability consisting only of those items that are most likely to be part of the fleet mix as affected by two major factors, optimal usage under conditions of energy shortage as described in the scenario materials, and level of support within the Coast Guard command structure as postulated by the preceding analysis.

Case A: All potential vehicles and Improved Technologies Available

1. Unit Variable

The addition of new vehicles and improved technologies has provided the Coast Guard with a markedly increased capacity to perform its ELT mission, although these have lesser effect on its increased MEP role. The availability of sensors and improved navigational systems increases the Coast Guard capacity to respond to SAR and other response mission needs, while the development of fuel cells and synthetic oil from shale have permitted the Coast Guard to maintain and increase its patrol activities.

The new vehicle and technological capacities thus increase the specialization of roles for vehicles - a condition that codes at a level of 8, increased from the 1980 coded level of 6 for the Unit Variable.

2. Program Variable

The situation described in the descriptive material provides that multiple and heterogeneous vehicles and technologies are involved; and that many of the relationships are sequentially ordered (e.g., a sensor reports an incident of some type, the information is collected at an intelligence and command center and a vehicle is dispatched to investigate) and orders to the units investigating an incident require that other units either back up or be ready to act should another incident occur while the first unit is performing its assignment. This situation then meets the descriptor for a coded

value of 8. This represents an increase from a 1980 value of 7; the increase being due to the greater sophistication required in command structure to optimize the use of the new vehicles and sensor reporting devices.

3. Boundary Variable

The sources of information are worldwide, at least in navigational aids (Omega, Loran C) and the GPS system. In addition the Coast Guard has added newer underseas responsibility for MEP as a result of offshore industrial developments. While many of these activities are scheduled - and thus more easily controlled and/or policed by the Coast Guard, both the natural conditions, e.g., storms, and the projected increase in smuggling make a fixed schedule of Coast Guard tasks impossible. In all cases, however, incidents require U.S. Coast Guard to bring its activities together at the locale of the incident. This variable thus is coded at a level of 8. The nature of the basic situation of response has not changed since 1980, which also codes at a level of 8.

Case B. Vehicles Limited to the most likely Fleet Mix

Examination of the probable attitudinal character of the command structure (Figure VI-3 above) shows that of the new vehicles and technologies available, only some could have entered the fleet. A "liberal" command attitude is predicted from circa 1977 to circa 1987. Most likely additions thus include MRS aircraft, WMEC 270' cutters and SRR helicopters. Possible additions are a few air cushion vehicles which may be added if the smuggling threat is strong. LORAN C and Omega systems are completed, and some remote sensors are utilized - but many of the potential new vehicles, new fuels, etc., are not adopted. In these circumstances the variables code as follows:

1. Unit Variable

With limited new vehicles in the fleet, and those which are added having operational characteristics similar to the current fleet, the coded response for this variable remains the same as in 1980: 6.

2. Program Variable

The relative similarity of the fleet mix, coupled with increased incident location capacity makes this area of control meet descriptor code levels at 7, with no significant increase from 1980.

3. Boundary Variable

Since there is no addition to the capacity of the Coast Guard to schedule its activities beyond that currently in force, the coded value remains the same as in 1980: 8.

2. Situation 2: Scenario 1990 Y

a. Description:

The major facets of this scenario are greatly increased terrorism and radical activity directed against the United States, with the response of the United States being increased police and military countermeasures. The Coast Guard plays a significant role with its size and budget doubled. While the scenario does not call for the

incorporation of the Coast Guard into the Department of Defense, it does specify that the ELT, PSS, and surveillance missions increase dramatically.

Technologically, the same possibilities obtain, which occured in the 1990 X scenario.

b. Analysis of Task Requisites

The basic Coast Guard task outlined in the scenario are increased Coast Guard counter terrorism measures and counterinsurgency capacity training. This means that there is a major focus on ELT and PSS missions, especially after the nuclear explosion off San Diego. The situation requires that the Coast Guard be placed on emergency status, but not yet incorporated into DOD. A large R&D effort is started in the use of remote surveillance sensors.

1. Size Variable

The greatly increased size, and the emergency status of the Coast Guard reflect the descriptor conditions that call for the addition of more and diverse units. Insofar as possible, all legitimate activities are scheduled so that anomalies can more easily be identified and tracked. Such scheduling probably would tend to becoming more or less fixed in the increased intelligence effort required by this scenario; that is, traffic could enter harbor areas only at established times under close supervision after inspection, etc. These activities would code as 9.

2. Adaptability Variable

The dramatically increased ELT and PSS missions make all of the other missions somewhat superfluous, and force all of the Coast Guard's attention to be centered on these basic concerns. Such a condition codes as 7.

3. Space/Time Variable

Inputs to the Coast Guard's arena of action come from multiple sources. Task missions are more scheduled in response to the need for greater control over coastal and harbor traffic, although such a schedule is not inflexible. Such a situation codes at a level of 8.

c. Analysis of Organizational Responses

Following our presentational design, organizational responses will again be presented in two formats; the case where all of the available technologies and/or tactical modifications available are applied, and the second instance which concerns the most likely fleet mix.

Case A: All Technologies Available Adopted.

The three variables in this instance code as reported in situation 1, the 1990 X scenario, since technological innovations are considered time bound in these analyses. The beginnings of a large R&D effort for remote surveillance in 1990 however, may cut lead times for these devices, so that some new possibilities for these to enter the fleet prior to 2000 exist.

Case B: Most Likely Fleet Mix.

The growing terrorist threat, and the limitations of domestic nuclear power development since 1985 in this scenario would tend to increase the adoption of more new technologies, especially in the areas of surveillance, new fuel sources and high performance pursuit vessels. The fleet would thus probably add hydrofoils, surface effect ships and a variety of unmanned and non-vehicle technologies (buoy based Dewline, drone patrol aircraft, remote sensors, GPS, etc.).

These new technologies represent most of the vehicles that are forecast as available in 1990. Accordingly the organizational responses code as those in case A.

3. Situation 3: Scenario 1990 Z

a. Description:

The basic conditions reported in this scenario include a fairly severe decline in the U. S. economy accompanied by a growth of internal terrorism and ecotage. There is increased utilization of offshore facilities and there are beginnings of extensive off-shore industries by this time period. Many government functions are regionalized, and central control tends to decline. This latter trend also applies to the Coast Guard as numerous functions and missions are decentralized. The Coast Guard does begin to develop a new USS mission and capability.

Technologically, the situation is the same as in the case of the 1990 X scenario.

b. Analysis of the Task Requisites; scenario 1990 Z

The decentralization of most Coast Guard functions and the addition of an initial USS mission and capability are the salient changes in tasks for the Coast Guard in this scenario situation.

1. Size Variable

The regionalization of the Coast Guard in many of its missions means that the number and types of units that are available at any one time are limited; reinforcement of units between areas becomes difficult, so that the size aspect of the Coast Guard declines to a coded level of 3.

2. Adaptability Variable

The addition of a new USS mission forces this coded level to 8, an increase over the 1980 base line code of 4.

3. Space/Time Variable

The regionalization of Coast Guard activities tends to limit its activities so that the coded response decreases from the 1980 baseline value of 6 to a value of 5.

c. Analysis of Organizational Responses:

Case A: All Technologies Available

As noted above, technologies are time bound. However the cuts in government budgets and the regional structure of the Coast Guard in this scenario make the funding of new vehicles very difficult. If new technologies were to be used, they would only be token units; and their adoption would be primarily symbolic.

1. Unit Variable

The addition of the small numbers of new technologies leads to a greater degree of specialization than obtained in 1980, but the numbers are so limited by budget factors that the increased codings are limited to 7.

2. Program Variable

The smaller size of regional areas of concern, plus smaller budget bases for Coast Guard activity forces the required increase over 1980 baseline to be limited. Code levels thus represent a modest increase in sophistication needed to utilize the new technologies. Code 7.

3. Boundary Variable

The regionalization of the Coast Guard reduce the boundary of the area of action from the 1980 baseline. Code 7.

Case B. Most Likely Fleet Mix.

With severe budget limitations, regionalization of many Coast Guard functions, the number of units available becomes limited, and missions are prioritized, with many rescue functions being transferred to local police authorities.

1. Unit Variable

The localization of programs and the shifting of responsibility for several missions to other local agencies produces a drop in the codings from the baseline value to 5.

2. Program

Those missions that remain require more sophistication to guard against ecotage. There is greater dependence on sophisticated surveillance mechanisms and intelligence gathering. Code 8.

3. Boundary

Regionalization of Coast guard functions cuts the areas of responsibility to 7.

4. Situation 4: Scenario 2005 X

Description:

The basic thrust of this scenario is the rapid economic expansion that takes place after the problems of the period 1980-1990. As part of this economic development, there is widespread offshore industrial utilization of the continental shelf. Ecological regulation is strong, with the result that the Coast Guard assumes an increasing role in Marine Environmental Protection. There is adequate support for these activities.

Technologically, the period since 1990 has seen the development of various vehicles: SES, SWATH, Hydrofoils, LTAC, WIGES, and various unmanned vehicles. Non-vehicle technologies include MTCS. All of the various fuel and energy technologies are now potentially effective, coal and shale oil synthetics, fuel cells and solar energy stations.

b. Analysis of Task Requisites:

The primary task of the Coast Guard in this scenario for the time period 2005 is its MEP mission. The extensive development of off-shore industries and strict environmental controls make this the basic Coast Guard task. The Congress funds the MEP effort as needed.

1. Size Variable

The strict enforcement of environmental regulations force the Coast Guard to schedule offshore operations so that monitoring of potential hazards and pollution can be made effective. This emphasis on scheduling of activities moves this activity to a code level of 8 as against the baseline value of 4.

2. Adaptability Variable

The increasing concern for the MEP mission accompanied by the addition of new surveillance and sensor devices to aid in this task lead to a coding of 6 for this variable.

3. Space/Time Variable

The need to exercise control in the situation, now widely spread over the continental shelf means that the Coast Guard's area of responsibility is increased. This leads to a higher coding of 7.

c. Analysis of Organizational Responses:

Case A: All Technologies Available:

The Coast Guard has available to it a wide variety of new technologies. Fuel sources from coal and oil shale provide relief from shortages, and the adoption of non-vehicle and unmanned vehicles makes the surveillance of potential pollution and other environmental dangers effective. High performance vehicles are available to respond to incidents associated with the whole range of Coast Guard missions.

1. Unit Variable

The strong MEP role for the Coast Guard causes the agency to develop specialized teams to deal with special problems as offshore industry develops. This growing specialization and non-interchangability of the units forces a coding of 8.

2. Program Variable

The various tasks that are part of the Coast Guard's operations all involve the use of heterogeneous units, and with growing specialization assignment to cover an explicitly defined series of tasks or behaviors, e.g., oil spill, release of other pollutants in offshore settings, and clean-up of these, cause the assignment of a coded value of 8 for this variable.

3. Boundary Variable

Most of the offshore industries involve the collection of resources from different places, and their trans-shipment to a single point; a port or plant dock. In the scenario, the implications of strict environmental regulation are that many of these activities are scheduled in as far as this is possible. Such behaviors code at a level of 9.

Case B: Most Likely Fleet Mix.

Since the period concerned falls into a "liberal" attitudinal command structure, it is likely that the Coast Guard would adopt some new technologies. Since the primary mission in this scenario is MEP, the need for new technologies will probably center on sensors, MTCS, and specialized vehicles for dealing with MEP problems. The focus would be less on high performance vehicles per se.

1. Unit Variable.

The specialization of MEP task forces, and the control systems developed out of the application of sensors, satellites, etc., cause us to code this variable at a level of 7; not as complex or specialized as in the case where high performance vehicles also are part of the fleet.

2. Program Variable.

The situation here is similar to that in Case A, code remains at 8.

3. Boundary Variable.

The situation is again the same as in Case A. Code 9.

5. Situation 5: Scenario 2005 Y

a. Description:

By 2005, the incidence of terrorism and the open conflict have ended. The Coast Guard is reduced in size as peace returns. The projected depression in 2005, with its attendant political ideological emphasis on asecticism and conformity lead the Coast Guard to formulate contingency plans to increase its ELT missions. However, the 2005 mission profile is much like that of the baseline period 1980.

Technologically, all of the developments reported in situation 4 above obtain.

b. Analysis of Task Requisites:

1. Size Variable

The primary factor affecting Coast Guard behavior in 2005 is its reduction by half from the high levels of operations in the 1990's. Such a situation leads us to code the situation as same as in 1980 - level 4.

2. Adaptability Variable

While the Coast Guard is reduced to normal "peacetime" status, it does retain some of the sophisticated capability it developed in the 1990's, especially in the surveillance areas. This leads us to code the variable slightly higher than in 1980, at level 5.

3. Space/Time Variable

The normalization of Coast Guard responsibilities to a condition similar to the baseline period lead us to code this situation as level 6, the same as in 1980.

c. Analysis of Organizational Responses:

Case A: All Technologies Available.

The only technology considered in the technological forecasts above not fully available to the Coast Guard by 2005 is the WIGES, and with the cutbacks to normal duties, the fleet mix is surveyed to make optimal use of all of the technologies adopted in the 1990's when wartime conditions permitted the inclusion of numerous high performance vehicles and surveillance systems into the fleet.

1. Unit Variable

The fleet composition is specialized and complex, and many missions are assigned to specialized teams that make maximal use of the technologies available. Code 9.

2. Program Variable

The Coast Guard in its normalized role reverts to its 1980 baseline organizational format as far as programs for utilizing the fleet are concerned. Code 7.

3. Boundary Variable

A similar retreat to baseline conditions exists in the area assigned to Coast Guard jurisdiction. Code 8.

Case B. Most Likely Fleet Mix.

Both the war of the previous decade, and the "liberal" attitude of the command structure allow the Coast Guard to adopt and utilize new technologies. Since it is most likely that many if not all of the potential technologies available by 2005 have already been adopted because of the emergency situation portrayed in the scenario the values for this case would likely be the same as in Case A.

6. Situation 6: Scenario Z, 2005

a. Description:

The salient points of this scenario for the year 2005 includes the existence of well developed offshore industry, economic warfare between third world resource centers and developed European, Japanese and American industrial centers. There is a high degree of environmental regulation, on a world wide basis. The Coast Guard has a fully developed USS system including underwater cutters, and underwater SAR systems.

Technologically, the same situation as reported in situation 4 obtains.

b. Analysis of Task Requisites

The scenario predicts that MEP and associated USS missions tend to dominate the Coast Guard programs by 2005, although other missions are still part of the activities that the agency carries out.

1. Size Variable

The scenario projects economic recovery with large capital investments into industrial protection of the environment. Such efforts will probably begin to force a more rigid scheduling of industrial activities so that byproducts of various interactions between activities of separate industries do not produce harmful effects on the environment. This move toward more rigid control codes 9.

2. Adaptability Variable

Industrial systems, whether or not on shore, code 8.

3. Space/Time Variable

The international concern for environmental controls and the economic rivalry between developed and undeveloped nations creates a situation that is complex, but only semi-scheduled. Code 8.

c. Analysis of Operational Responses:

Case A: All Available Technologies

1. Unit Variable

The primacy of MEP and USS missions means that most of the technologies involved are tied to these missions, with emphasis on surveillance systems. High performance vehicles exist, but are used to patrol and respond to incidents throughout the offshore industrial centers. Such a situation codes 8.

2. Program Variable

The utilization of complex surveillance systems and the dispatch of vehicles requires a program that is selectively scheduled, but still flexible. Code 8.

3. Boundary Variable

Conditions are more complex than in situations described for the baseline with a highly developed offshore industrial development. Code 9.

Case B. Most Likely Fleet Mix

1. Unit Variable

Emphasis in new technologies would stress surveillance and rapid response to MEP incidents in the offshore industrial centers. This, combined with the "liberal" attitudinal focus of the command structure, would mean that many of the sensor and remote observation platforms developed in the immediate past plus selected high performance vehicles would probably be added to the fleet. Extensive USS facilities are also involved. Code 8.

2. Program Variable

Optimal utilization of available vehicles and technologies requires scheduling of transit of industrial products from offshore areas to ports. Code 8.

3. Boundary Variable

The need to protect the environment, and the growing concern over environmental use of offshore developments plus economic rivalry promotes an increase in the boundary aspects of Coast Guard responsibility. Code 9.

APPENDIX H
The Dynaship

Among the various domestic and foreign efforts directed toward the reintroduction of sail-powered commercial vessels, those of the Dynaship Corporation of Palo Alto, California, are the most ambitious. Their activities are directly based on the work of Wilhelm Proelss, a German engineer. In the mid-1950's, Proelss proposed a new type of rig for large sailing vessels. Beyond the use of new materials and design techniques, the essence of the Proelss concept is the remote control of sail setting, furling, and trimming. Under the control of automated equipment, large, square sails would be set by power-driven winches, unrolling along the yards from the center of the masts. The masts themselves would be rotated to trim the sails. Although under the direct control of a shipboard computer system, the process would take place under the supervision of a deck officer. Through the use of modern weather-forecasting technology, it would be possible for ships so rigged to follow the best tracks along their general routes, finding the best combinations of wind and current for fast passages.

The Proelss concept, the Dynaship, was taken up by the Hamburg Research Council. Under their sponsorship, extensive tests were conducted at the University of Hamburg's Shipbuilding Institute from 1961 to 1967. These studies focused upon a comparison between a "conventional" sailing ship and a Dynaship in the following areas: (1) aerodynamic improvements possible using the Proelss rig; (2) a comparison of tripod with elliptical-cross-section masts; (3) optimization of yardarm curvature; (4) the effects of sail reefing; and (5) optimization of the number of masts, spacing, and sail trim to maximize sail efficiency (Ref. H-1).

Proelss proposed the construction and operation of a "demonstration" vessel. This was to be a 462-foot cruise ship capable of carrying 280 passengers with a crew of 140. After some initial progress, the German effort stalled over problems of financing, which involved amounts in the range of ten to twenty million dollars (Ref. H-2).

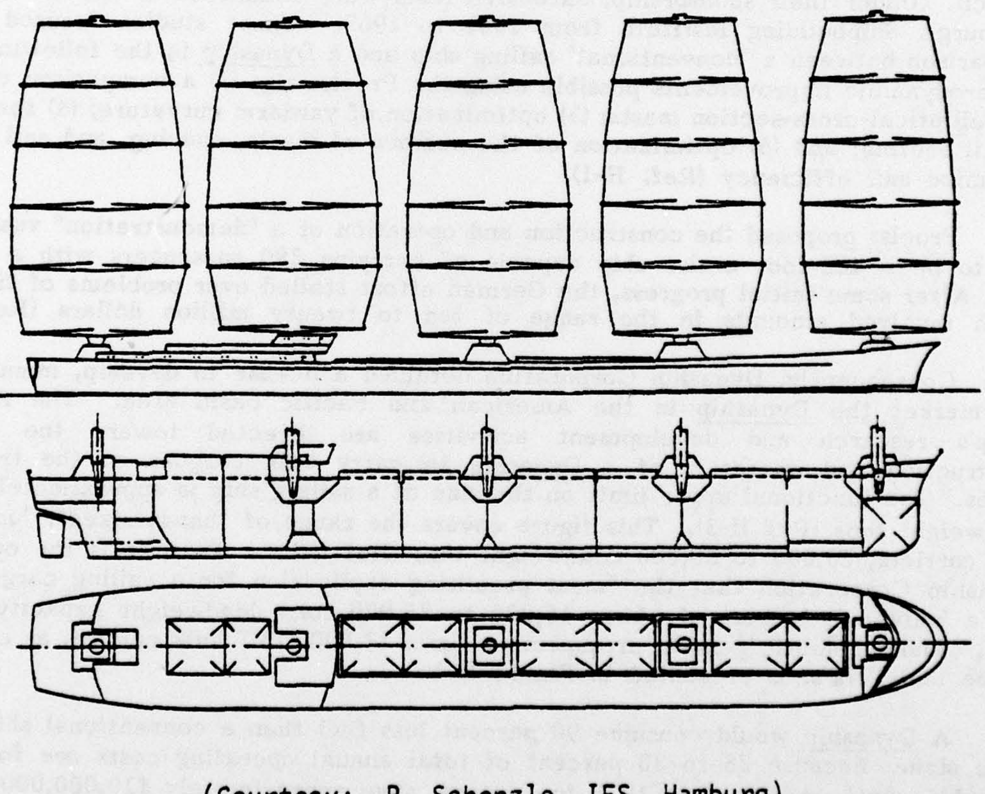
Consequently, Dynaship Corporation obtained a license to develop, manufacture, and market the Dynaship in the American and Pacific basin area. The American group's research and development activities are directed toward the eventual construction and operation of a Dynaship to carry bulk cargoes on the traditional routes. The functional upper limit on the size of a sailing ship is approximately 45,000 deadweight tons (Ref H-3). This figure covers the range of "handy-sized", "universal", bulk carriers, 20,000 to 30,000 deadweight tons (Ref. H-1). Thus, it is the opinion of Dynaship Corporation that the "most promising application for a sailing cargo ship is (as) a 'universal bulker' of about 15,000 to 25,000 tons deadweight capacity." (Ref H-1). The schematic general arrangement for a 17,500 DWT bulk carrier, as conceived in the mid-1970's, is presented in Figure H-1.

A Dynaship would consume 90 percent less fuel than a conventional ship of the same size. Because 25 to 30 percent of total annual operating costs are for fuel, a Dynaship could, measured in 1975 fuel prices, save approximately $10,000,000 over its operating lifetime (Ref. H-3).

Dynaship Corporation's preliminary designs have been approved by American Bureau of Shipping, and are currently being studied by the United States Coast Guard for load line assignment and stability calculation.

In addition, Dynaship Corporation is currently at work on the construction of a prototype vessel. Current plans call for the purchase and conversion of a 286-foot, 3,000-ton hull. The completed vessel will carry containerized cargoes between West Coast ports and Tahiti (Ref. H-4).

Under conditions of resource scarcity and continually increasing fuel prices, it appears that the Dynaship comprises a promising line of research and development.



(Courtesy: P. Schenzle, IFS, Hamburg)

Figure H-1: Dynaship

REFERENCES

H-1 Warner, W. L., "Updating an Ancient Art - Research and Development Toward Modern Wind Powered Cargo Ships". Paper presented at the Spring Meeting/STAR Symposium, San Francisco, California, May 25-27, 1977.

H-2 Englebert, R. M., "Dynaship: Economical Cargo Carrier with Push-Button Sails". Popular Science, April, 1976, pp. 58-59.

H-3 "DYNASHIP", Dynaship Corporation, Palo Alto, California, 1975.

H-4 Telephone Interview with William L. Warner, held May 31, 1978.

GLOSSARY OF ACRONYMS

The following acronyms are used in this report.

ACV	-	Air Cushion Vehicle
ANB	-	Aids-to-Navigation Boat
ANT	-	Aids to Navigation Team
DF	-	Direction Finder
ELT	-	Electronic Location Transmitter (Transponder)
EPIRB	-	Emergency Position Indicating Radio Beacon (Transponder)
FW/AC	-	Fixed Wing Aircraft
GPS	-	Global Positioning System (Satellite Navigational Aids)
HEC	-	High Endurance Cutter
HYD	-	Hydrofoil
LES	-	Low Energy Setting
LRS	-	Long Range Search
LTAV	-	Lighter-Than-Air-Vehicle
MEC	-	Medium Endurance Cutter
MLB	-	Motor Life Boat
MRB	-	Motor Rescue Boat
MRR	-	Medium Range Recovery
MRS	-	Medium Range Search
MTCS	-	Maritime Traffic Control System
NSFO	-	Navy Ship Fuel Oil
PB	-	Patrol Boat
PHM	-	Patrol Hydrofoil Missle
P of O	-	Platform of Opportunity
PWB	-	Ports and Waterways Boat
RW/AC	-	Rotary Wing Aircraft (Helicopter)
SES	-	Surface Effect Ship
SFC	-	Specific Fuel Consumption
SK	-	Skiff
SOP	-	Standard Operating Procedure
SRR	-	Short Range Recover.
UTB	-	Utility Boat (Large)
UTM	-	Utility Boat (Medium)
VTOL	-	Verticle Takeoff and Lift Vehicle